US009086242B2

(12) **United States Patent**
Newman, Jr.

(10) **Patent No.: US 9,086,242 B2**
(45) **Date of Patent: Jul. 21, 2015**

(54) **SLAG CLEARING SYSTEM AND METHOD**

(71) Applicant: **Nucor Corporation**, Charlotte, NC (US)

(72) Inventor: **David Gordon Newman, Jr.**, Mt. Pleasant, SC (US)

(73) Assignee: **Nucor Corporation**, Charlotte, NC (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 108 days.

(21) Appl. No.: **13/842,132**

(22) Filed: **Mar. 15, 2013**

(65) **Prior Publication Data**

US 2014/0265066 A1 Sep. 18, 2014

(51) **Int. Cl.**
F27D 25/00 (2010.01)

(52) **U.S. Cl.**
CPC ***F27D 25/001*** (2013.01)

(58) **Field of Classification Search**
CPC F27D 25/001
USPC 266/135, 287
See application file for complete search history.

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Primary Examiner — Scott Kastler
(74) *Attorney, Agent, or Firm* — Moore & Van Allen, PLLC; Jeffrey R. Gray

(57) **ABSTRACT**

Embodiments of the present invention comprise systems and methods that clear (e.g., break-up, remove, or the like) the solidified slag (e.g., slag that is solidifying or has at least partially solidified) from the furnace, such as from the slag door as molten slag is removed from the furnace. The systems and methods of the present invention comprise utilizing an arm that is extendable and retractable into and out of a position for accessing an opening in a slag door. The system has a ram that extends and retracts, and may move in horizontal and vertical directions, to clear solidified slag from the slag door opening and other areas within a furnace. The systems and methods of the present invention provide for clearing of solidified slag from the furnace without putting workers in a dangerous environment and without the need for expensive retrofitting of the furnace or furnace deck.

26 Claims, 18 Drawing Sheets

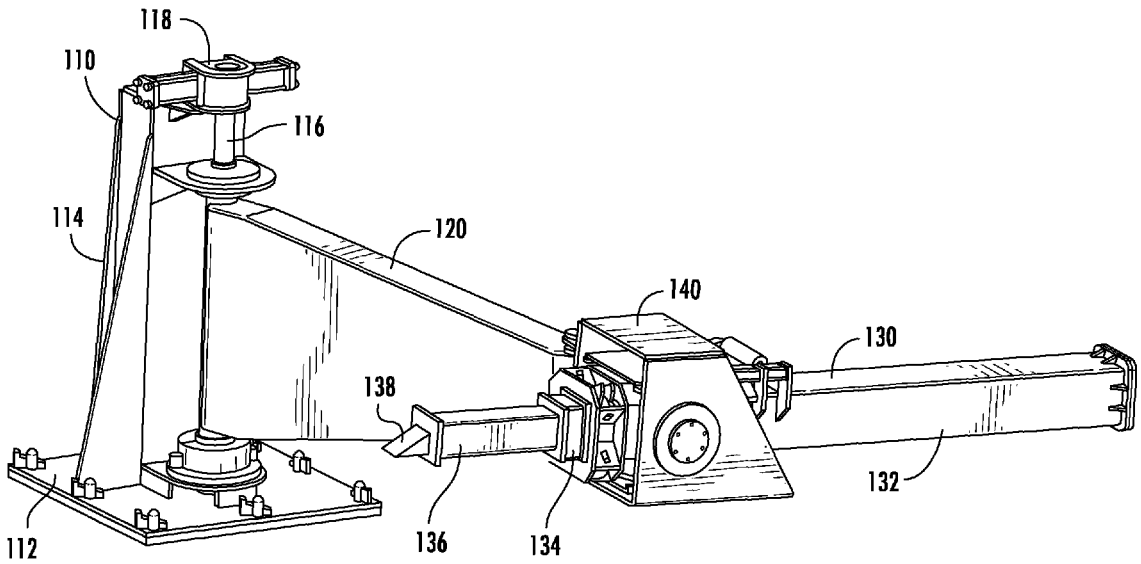
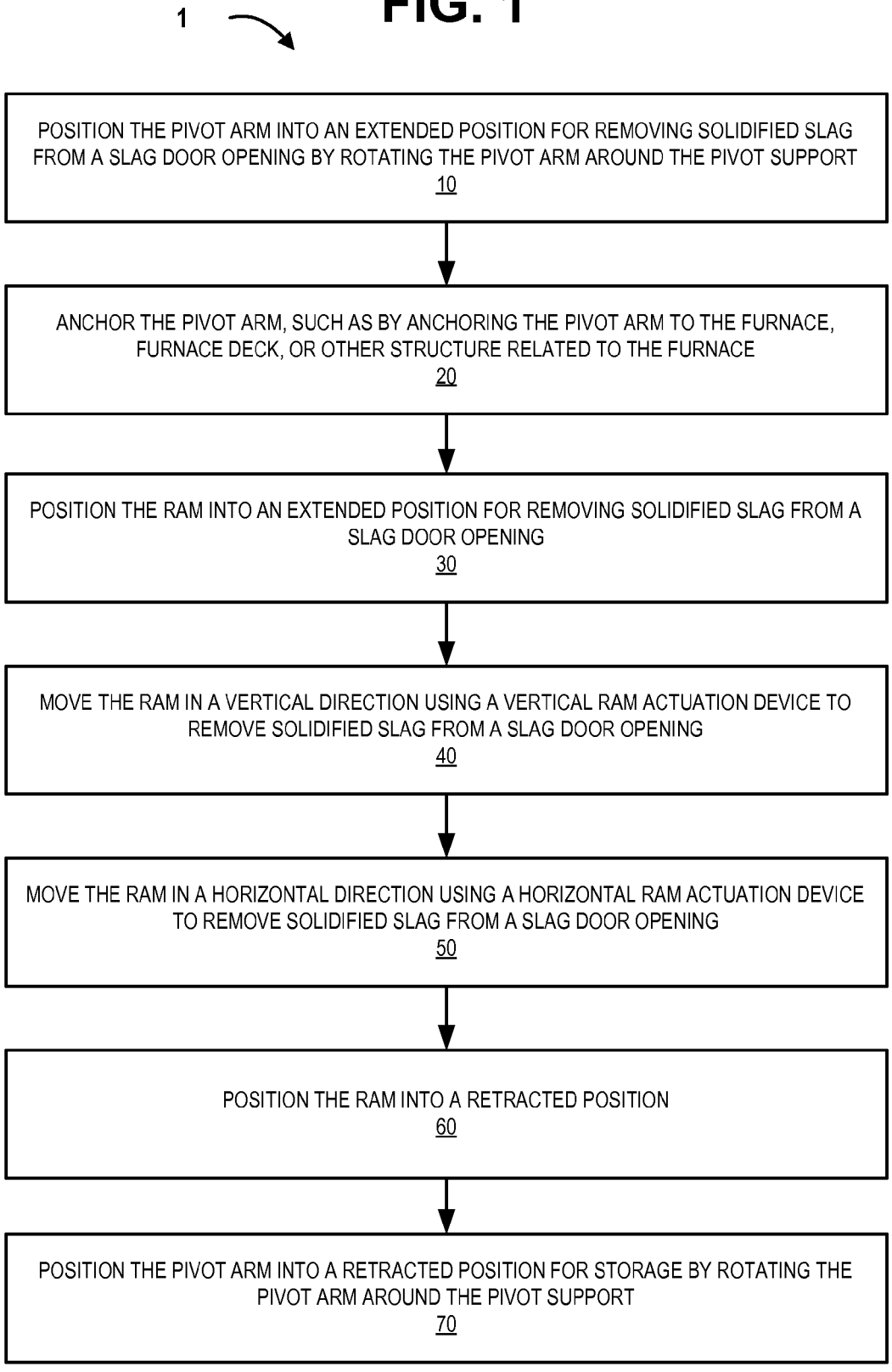


FIG. 1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POSITION THE PIVOT ARM INTO AN EXTENDED POSITION FOR REMOVING SOLIDIFIED SLAG FROM A SLAG DOOR OPENING BY ROTATING THE PIVOT ARM AROUND THE PIVOT SUPPORT
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ANCHOR THE PIVOT ARM, SUCH AS BY ANCHORING THE PIVOT ARM TO THE FURNACE, FURNACE DECK, OR OTHER STRUCTURE RELATED TO THE FURNACE
20
POSITION THE RAM INTO AN EXTENDED POSITION FOR REMOVING SOLIDIFIED SLAG FROM A SLAG DOOR OPENING
30
MOVE THE RAM IN A VERTICAL DIRECTION USING A VERTICAL RAM ACTUATION DEVICE TO REMOVE SOLIDIFIED SLAG FROM A SLAG DOOR OPENING
40
MOVE THE RAM IN A HORIZONTAL DIRECTION USING A HORIZONTAL RAM ACTUATION DEVICE TO REMOVE SOLIDIFIED SLAG FROM A SLAG DOOR OPENING
50
POSITION THE RAM INTO A RETRACTED POSITION
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POSITION THE PIVOT ARM INTO A RETRACTED POSITION FOR STORAGE BY ROTATING THE PIVOT ARM AROUND THE PIVOT SUPPORT
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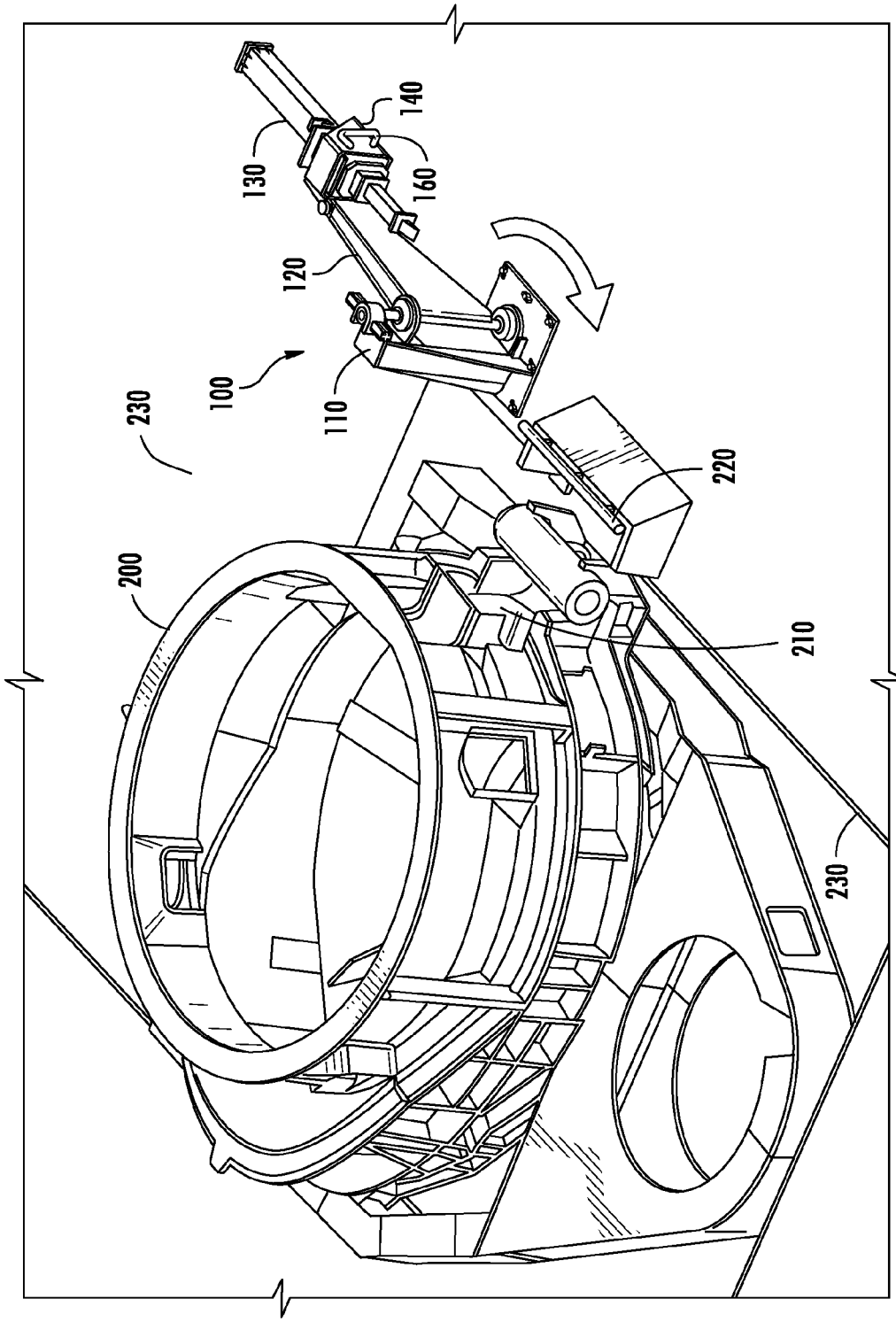

FIG. 2

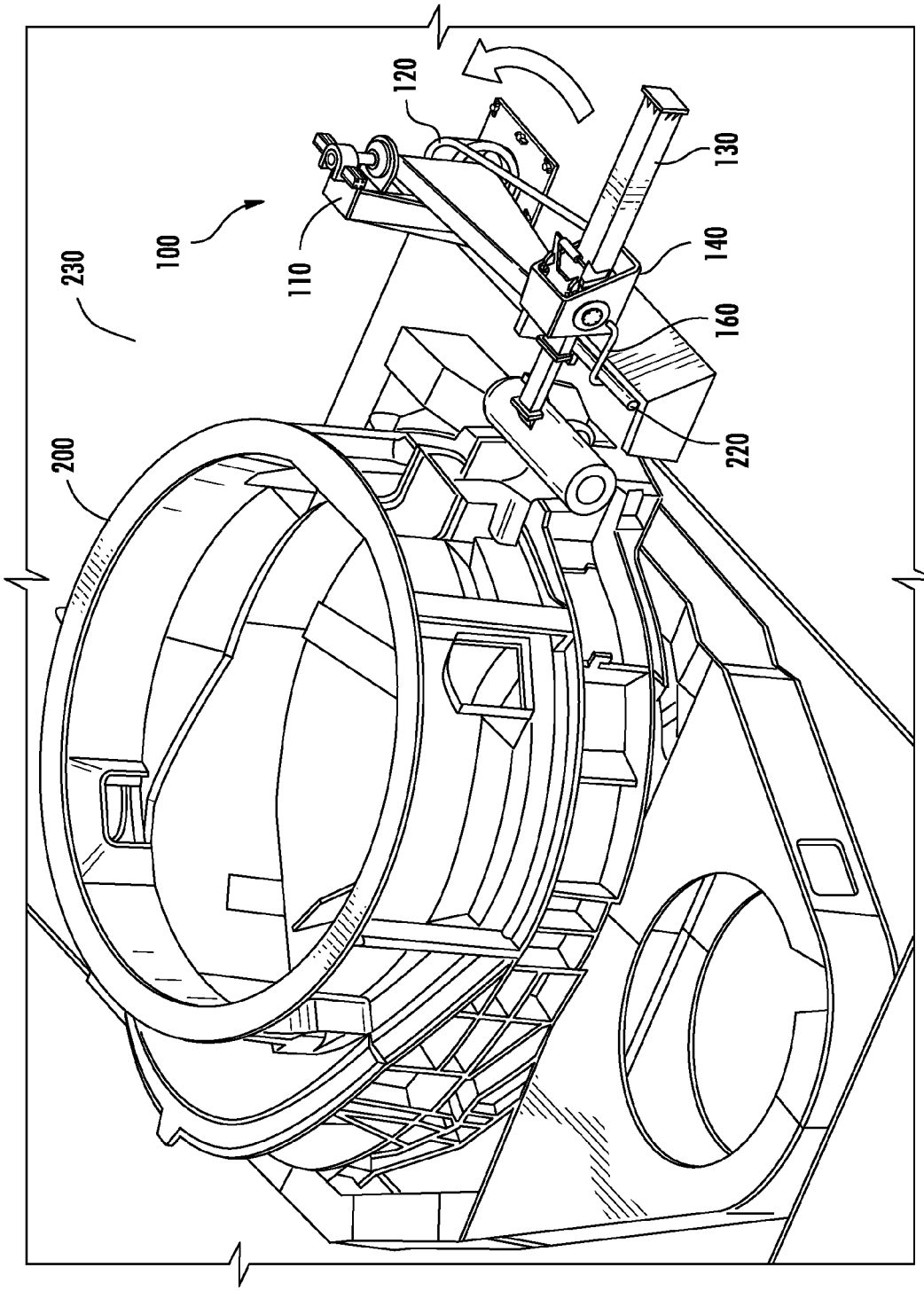

FIG. 3

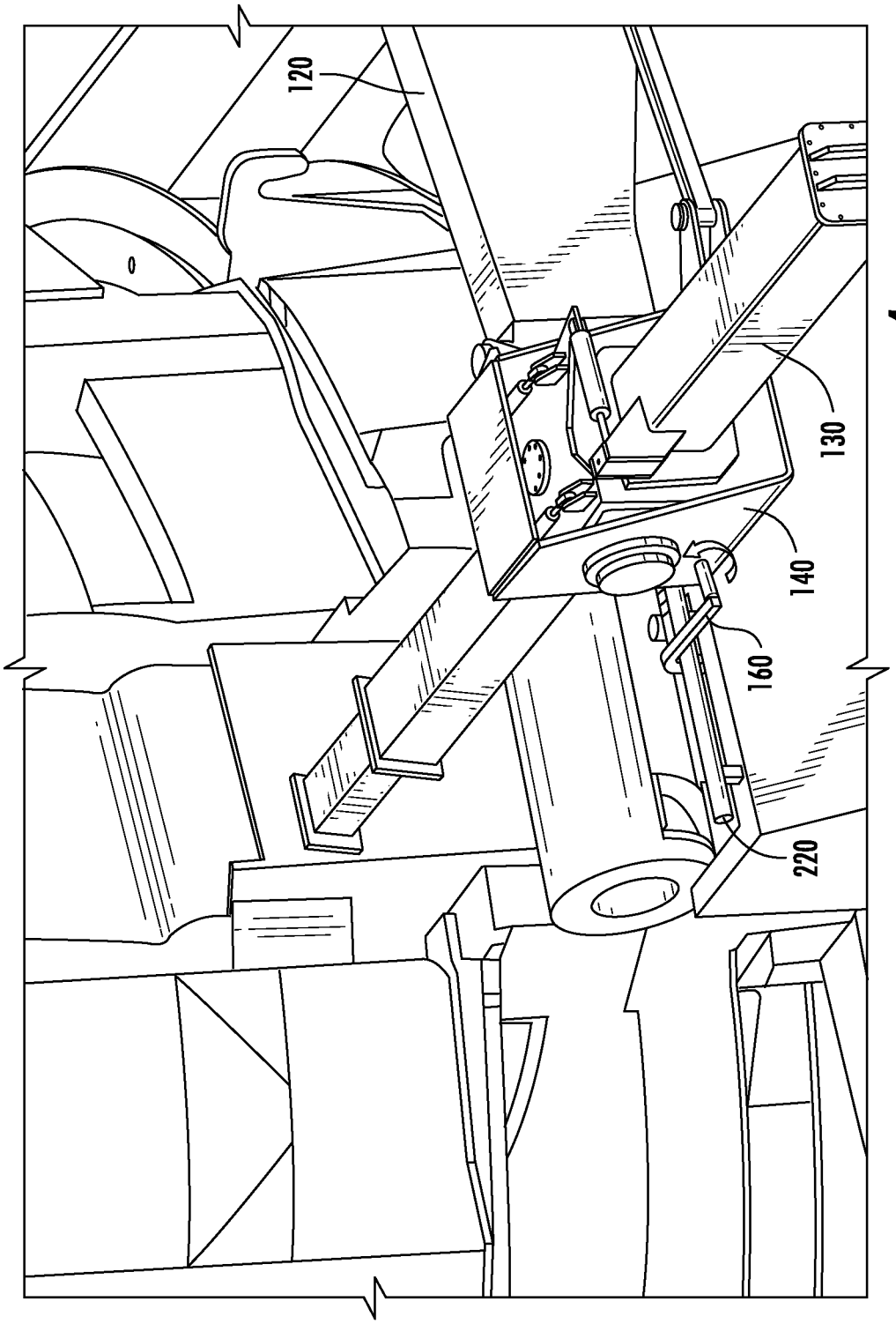

FIG. 4

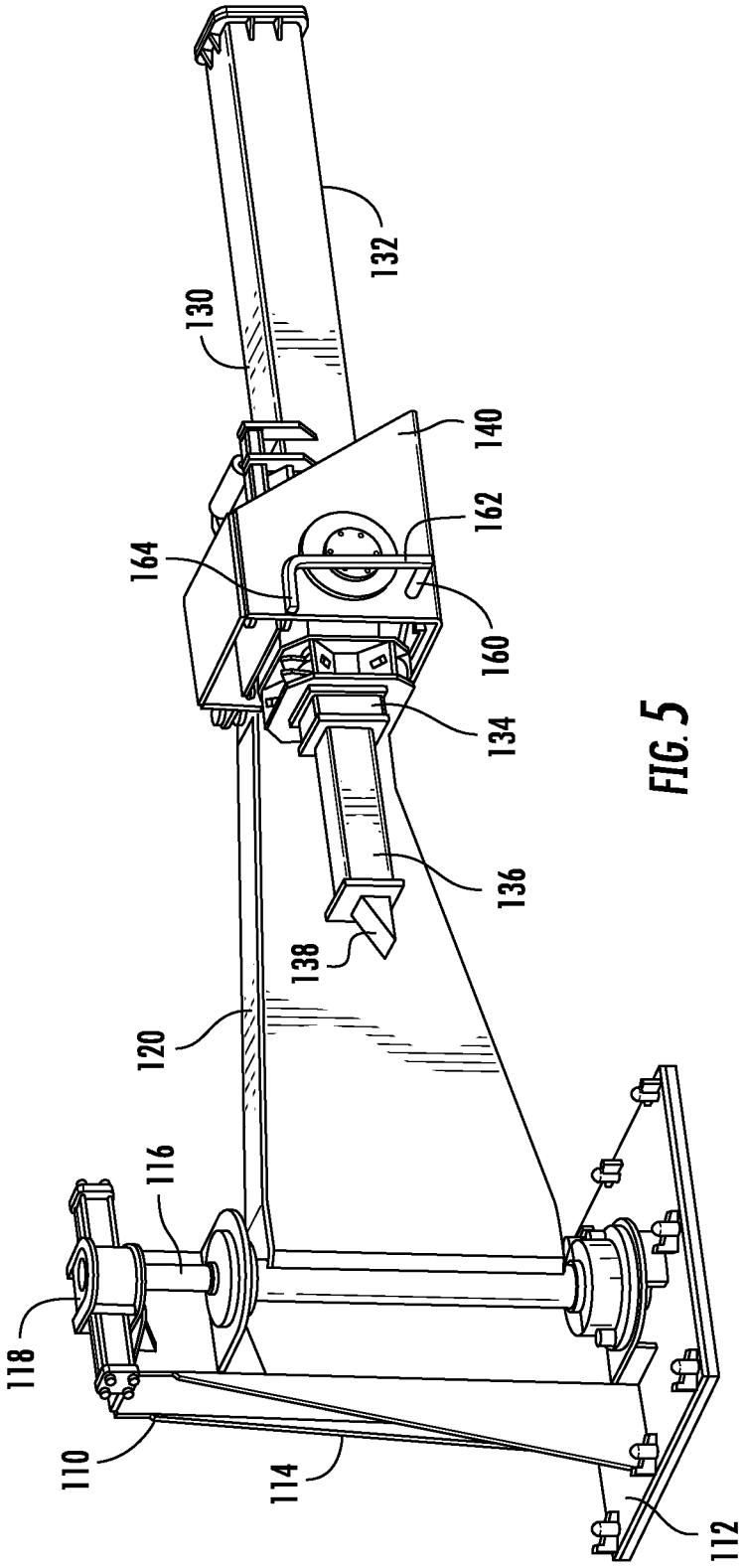

FIG. 5

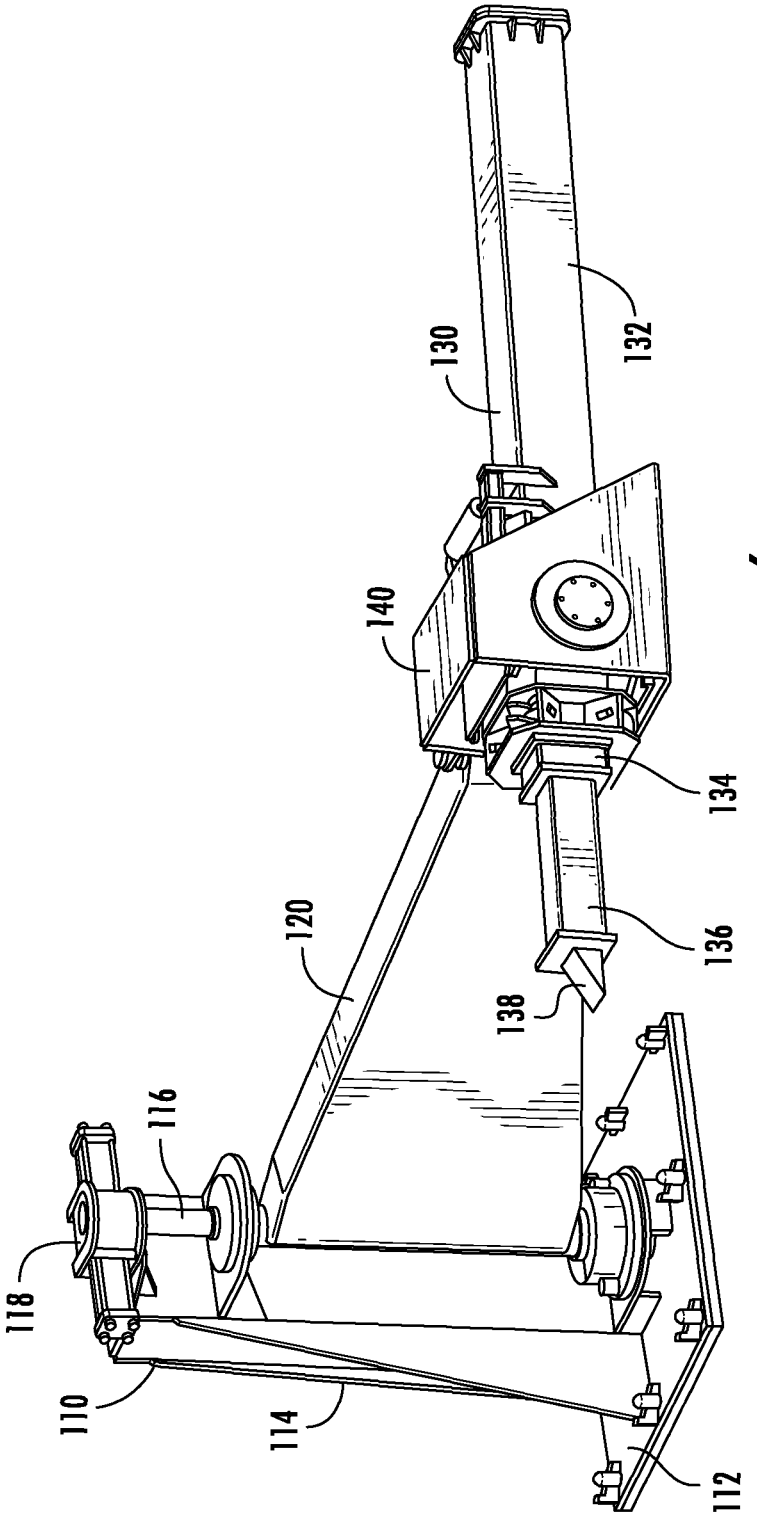

FIG. 6

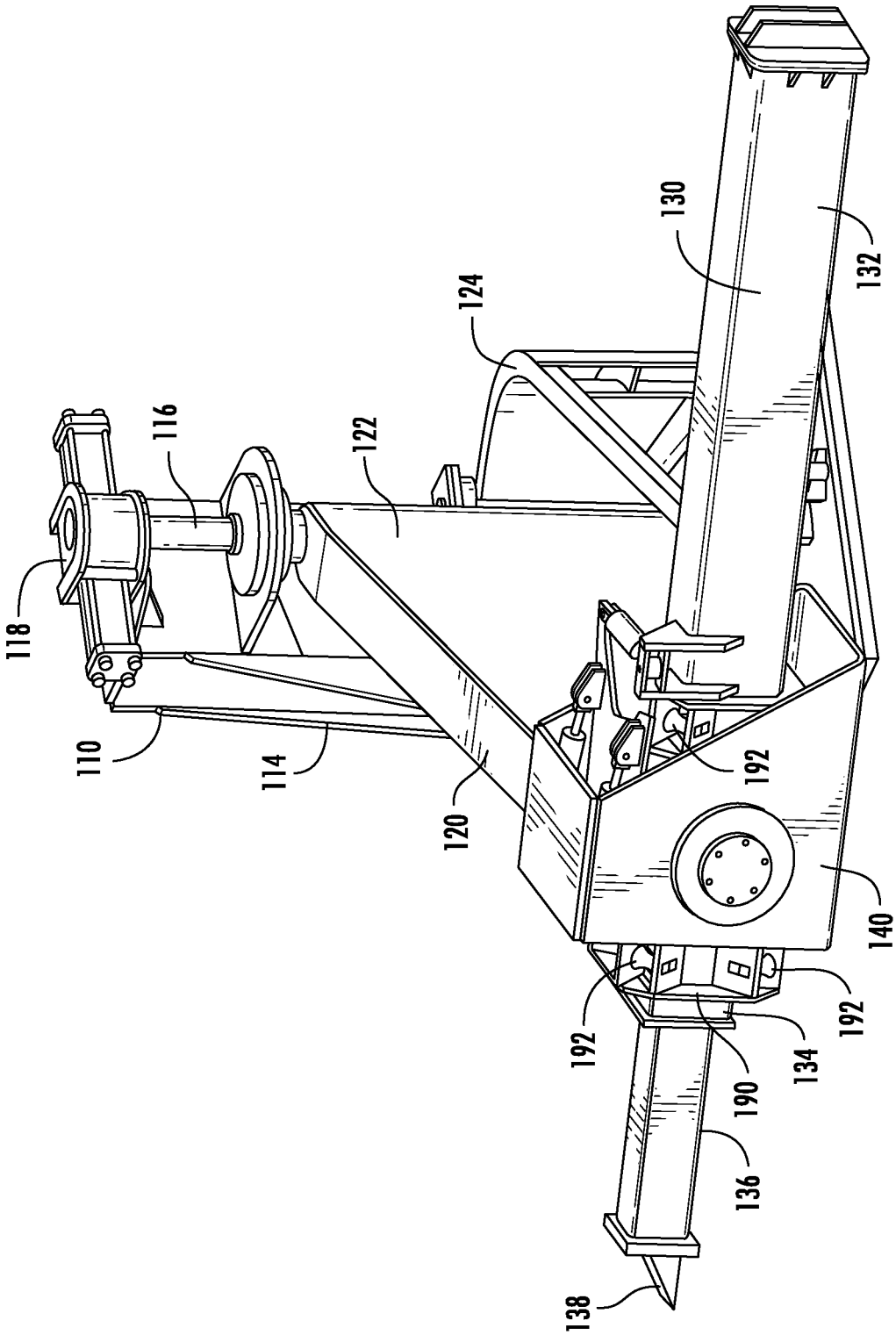
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FIG. 7

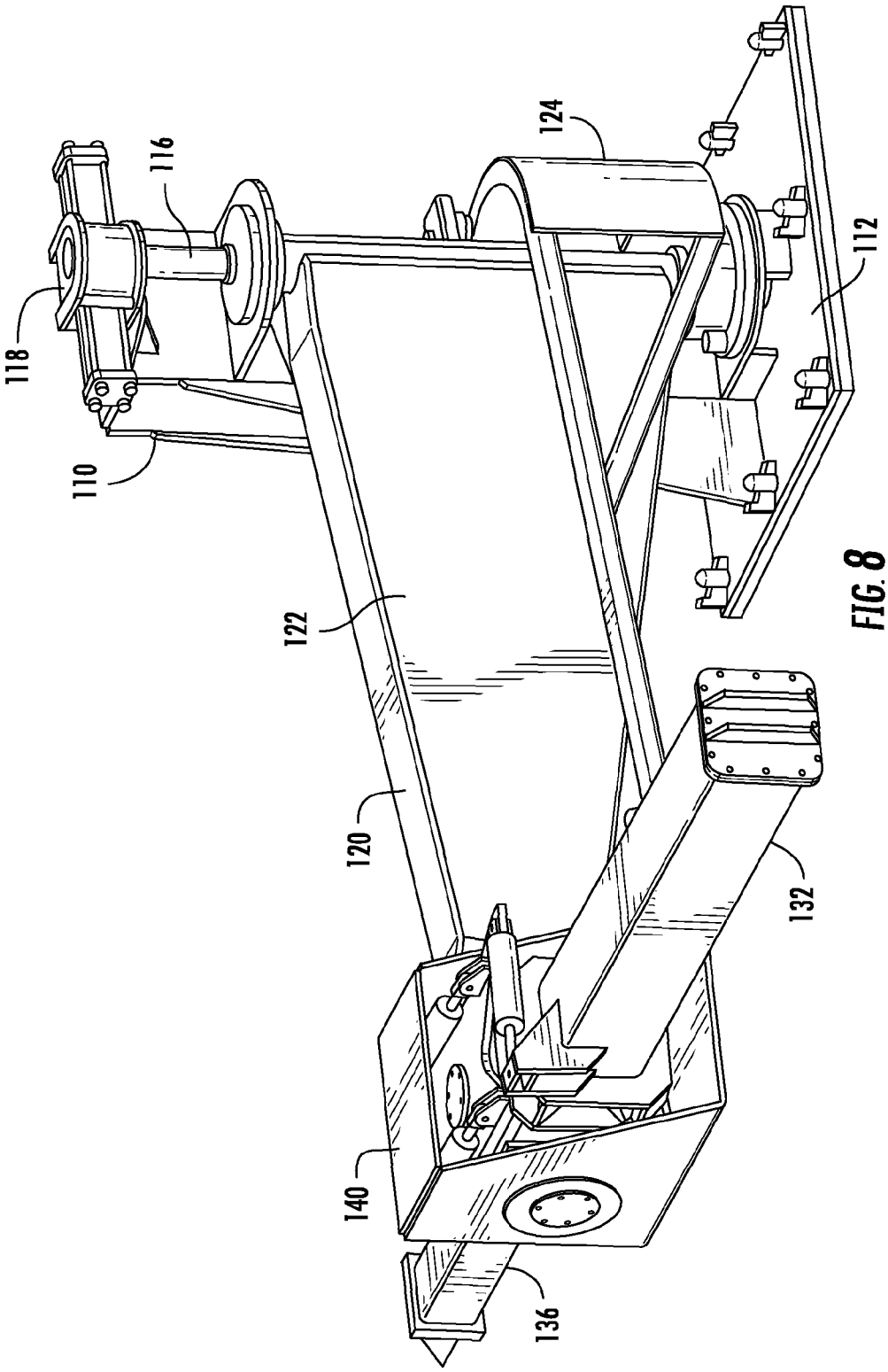

FIG. 8

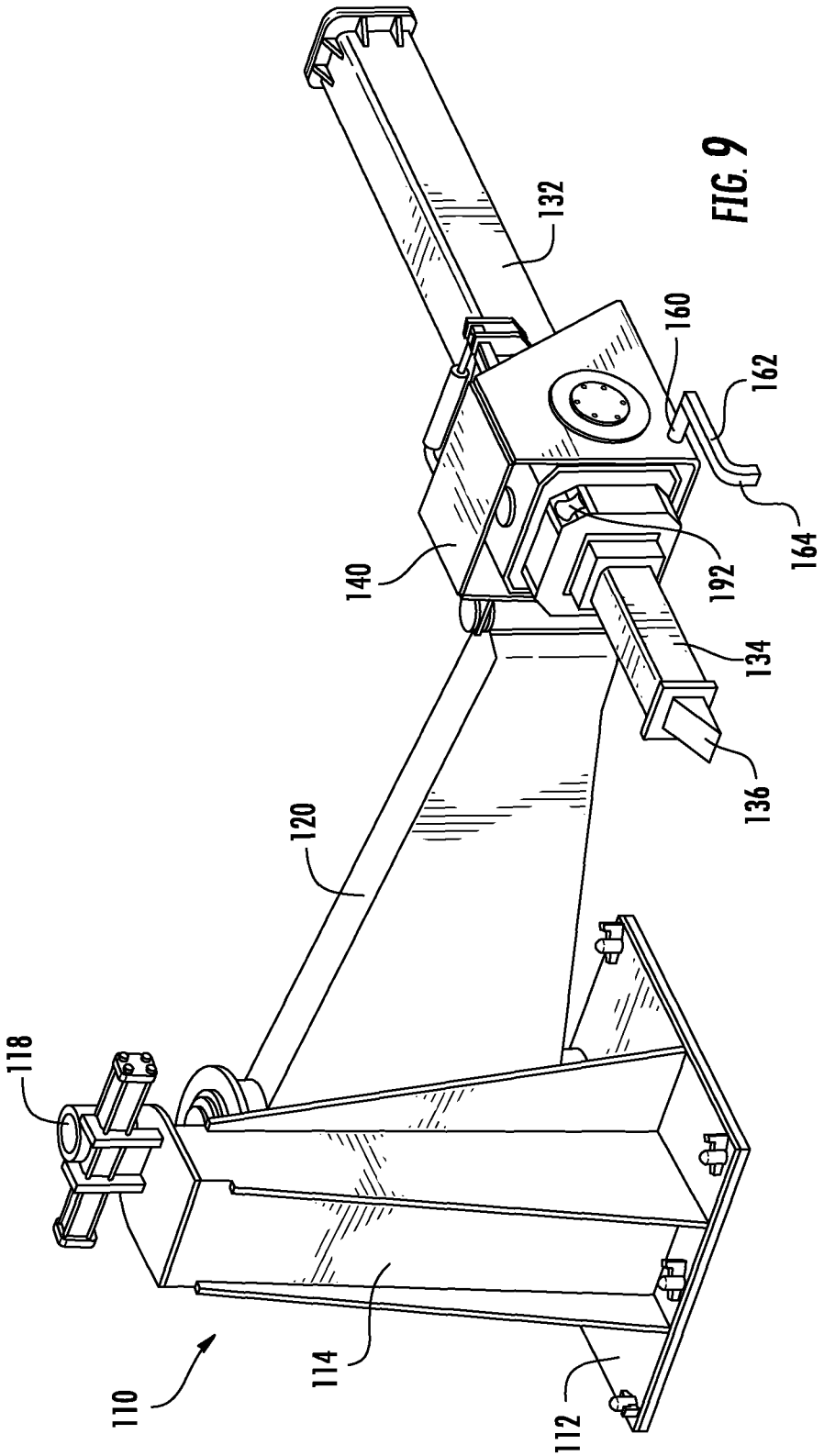

FIG. 9

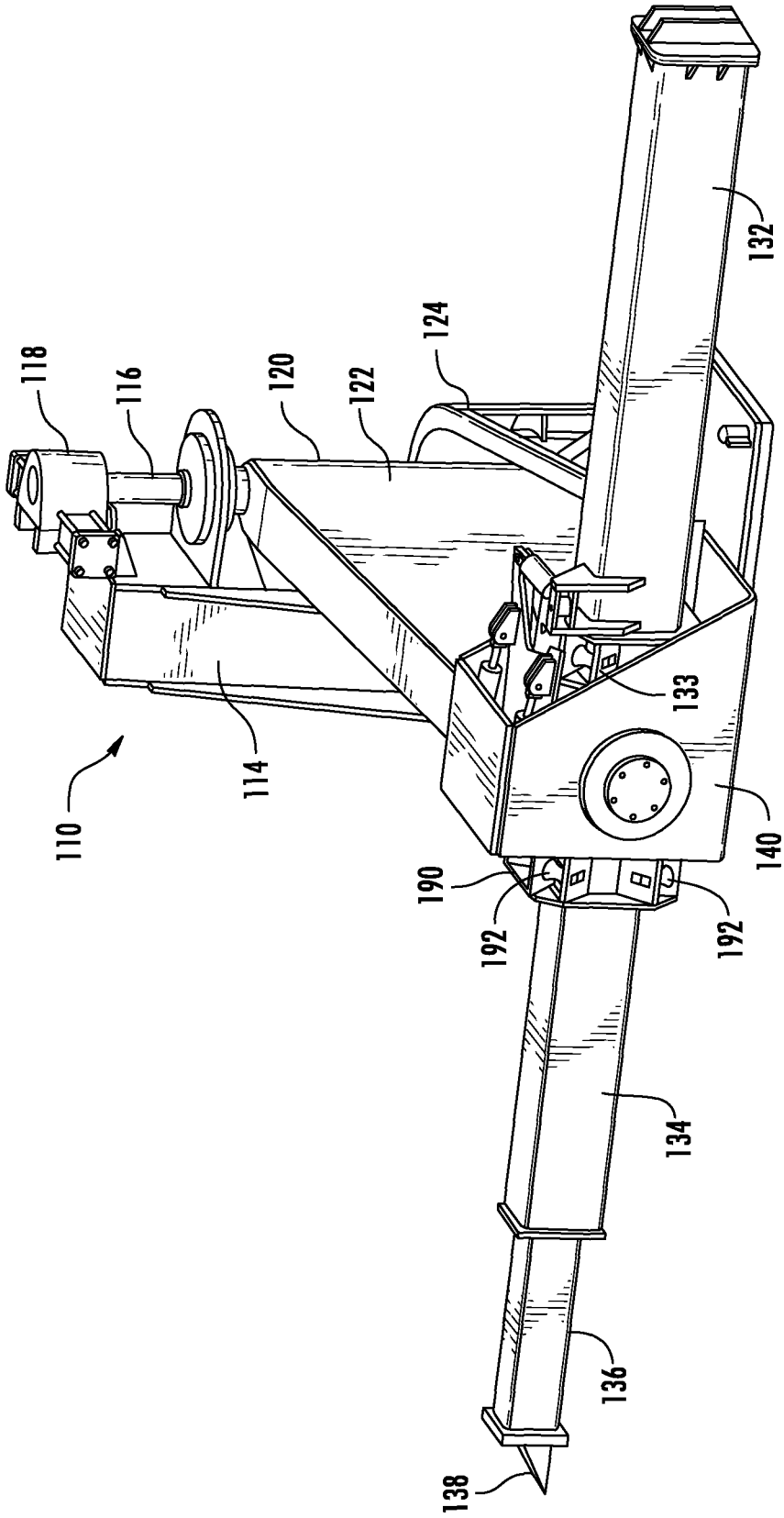

FIG. 10

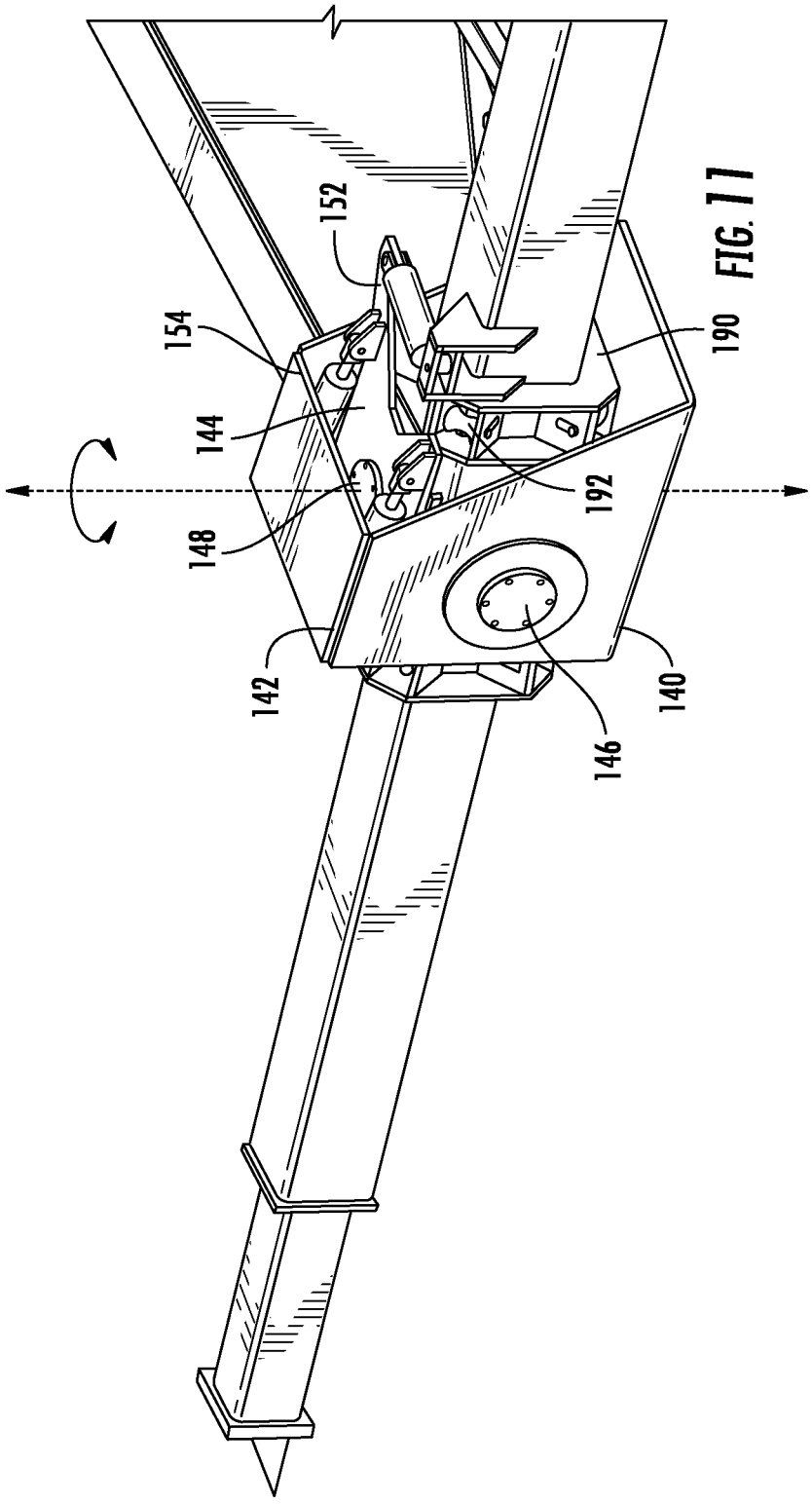

FIG. 11

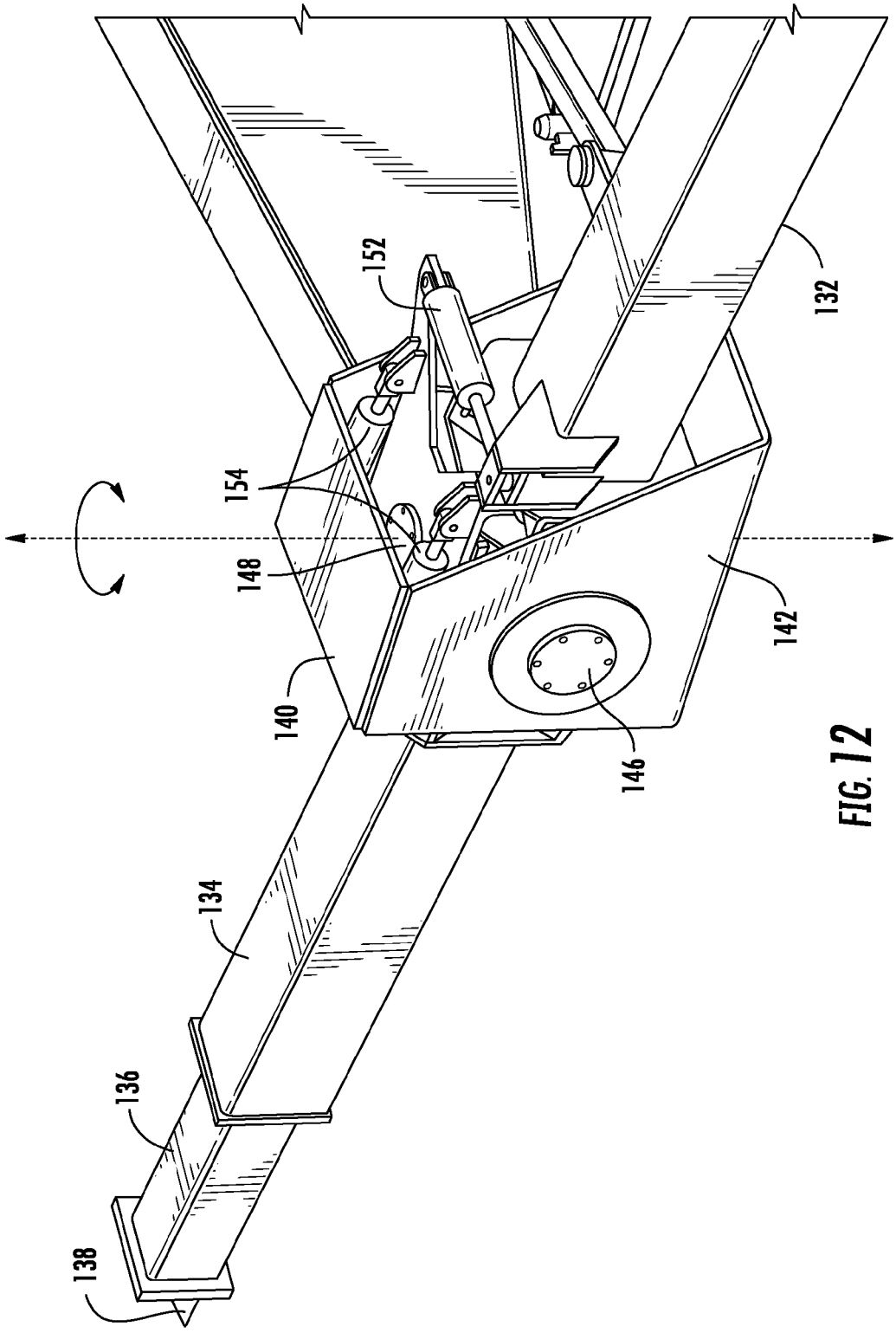

FIG. 12

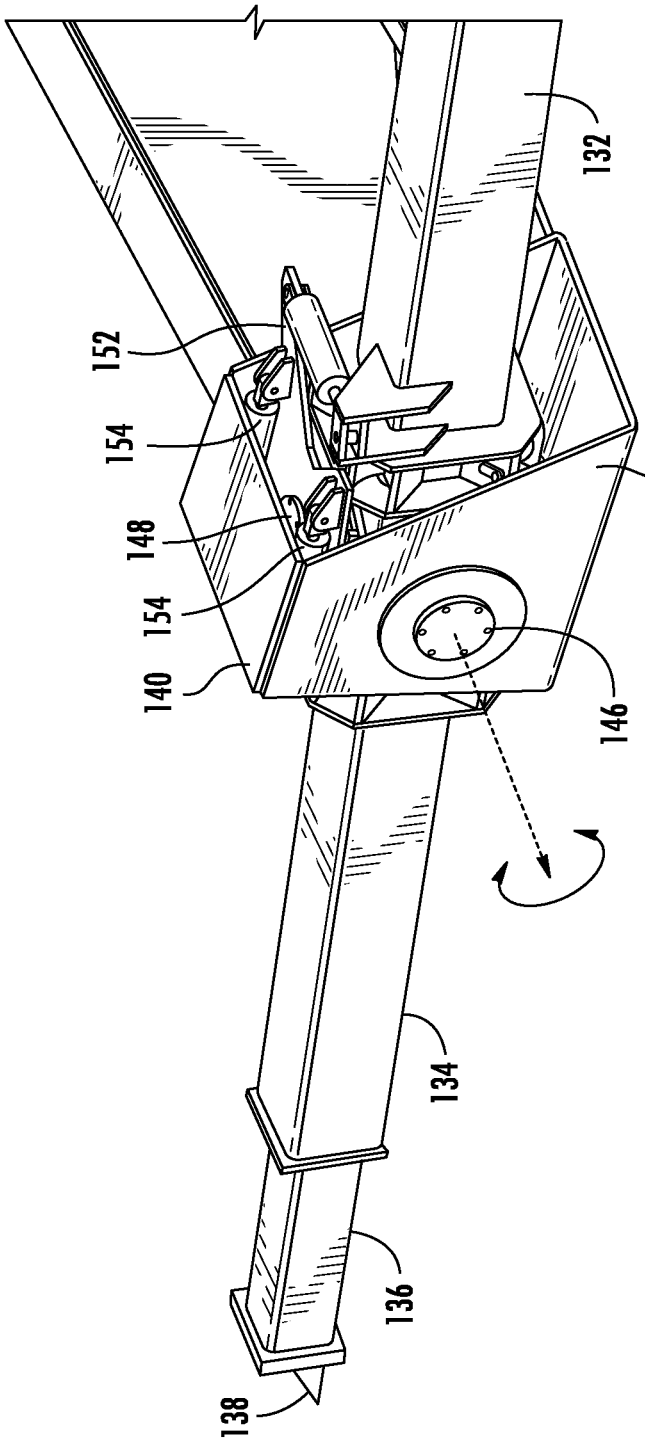

FIG. 13

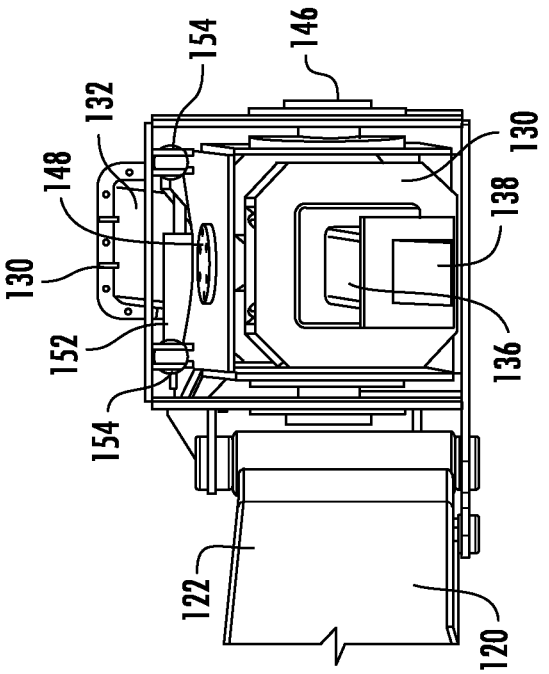
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FIG. 15

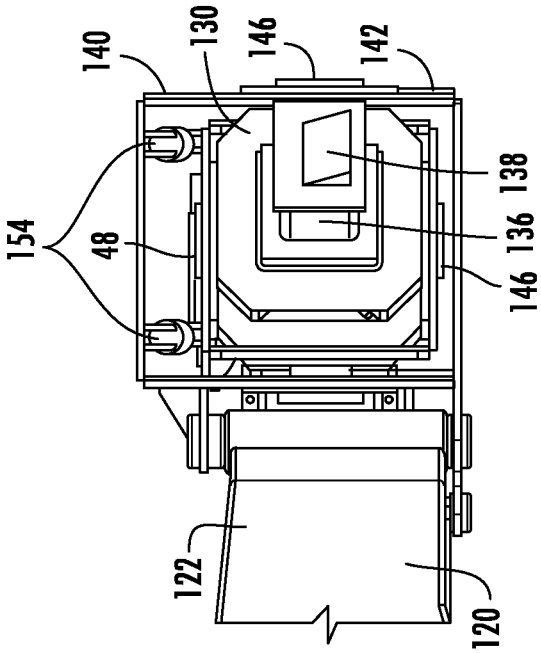
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FIG. 14

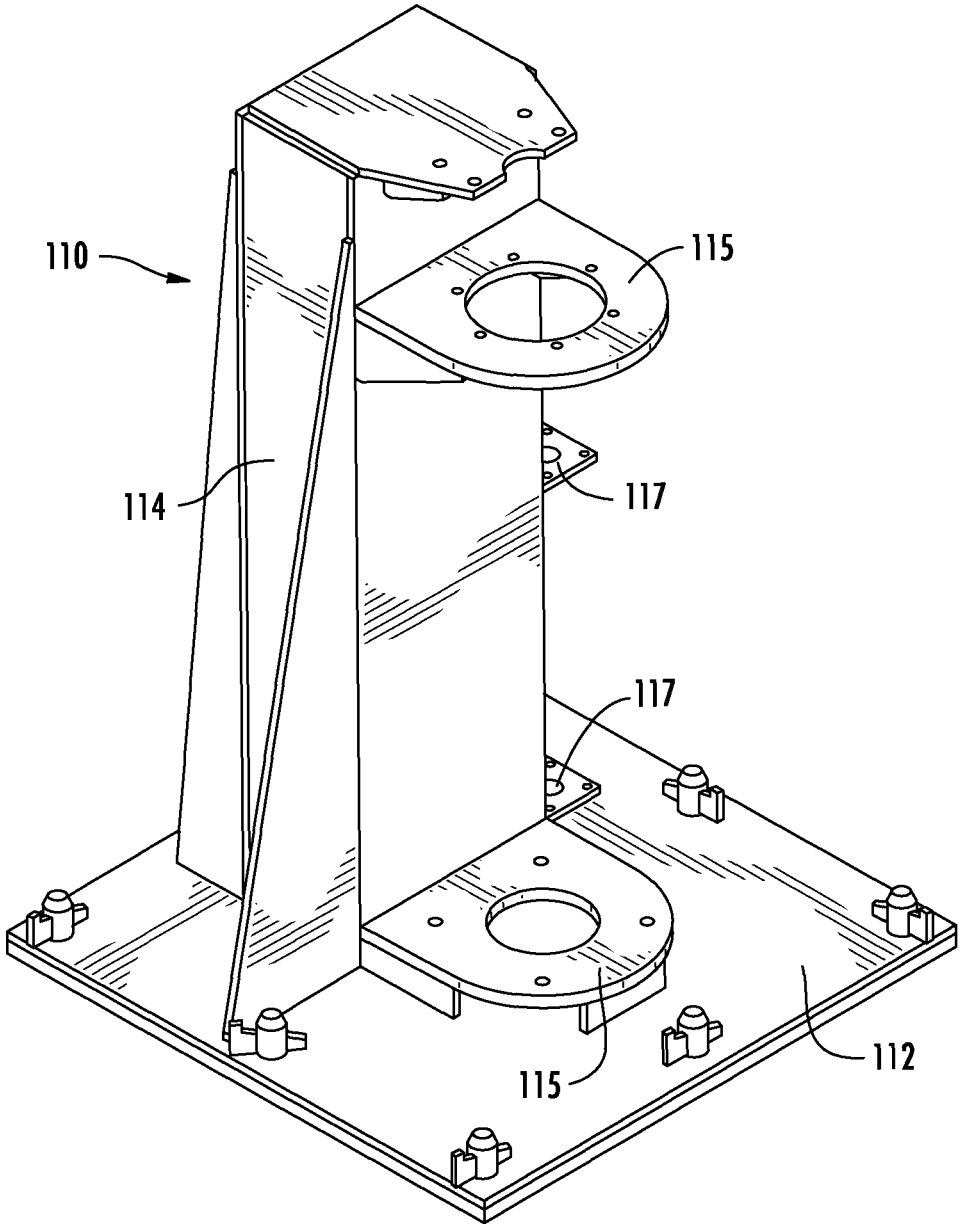

FIG. 16

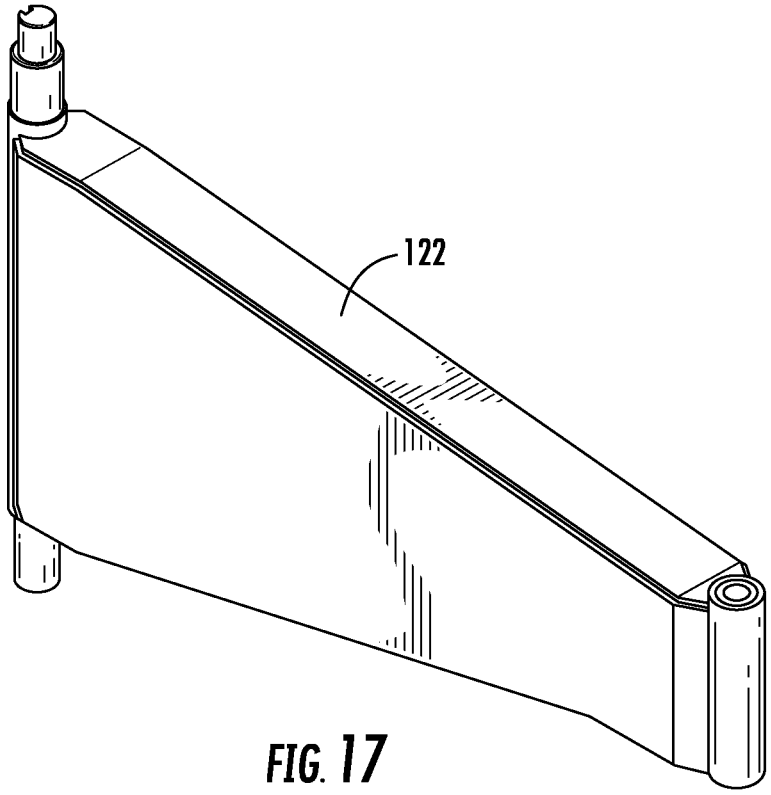

FIG. 17

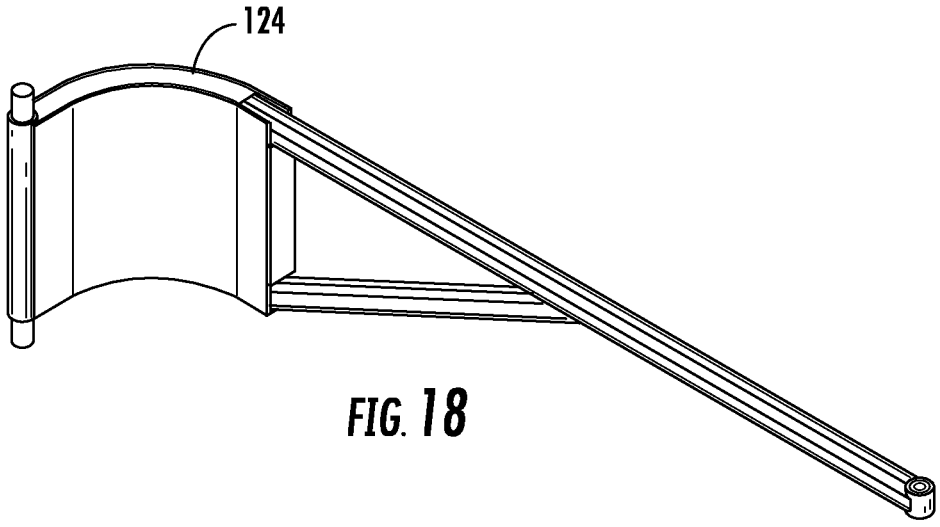

FIG. 18

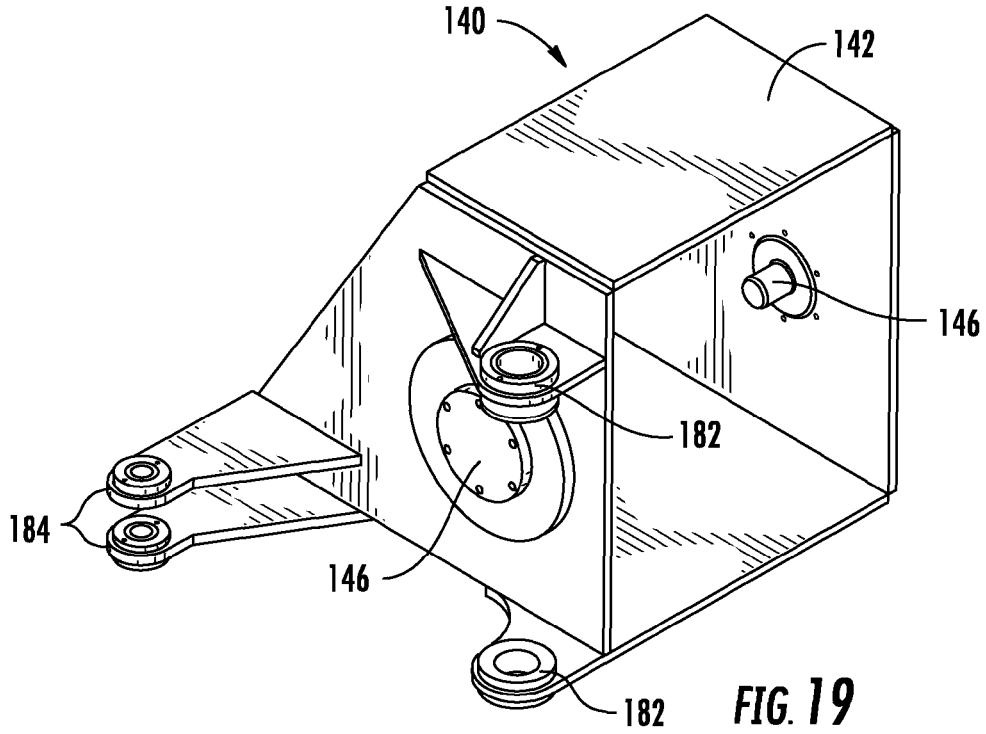

FIG. 19

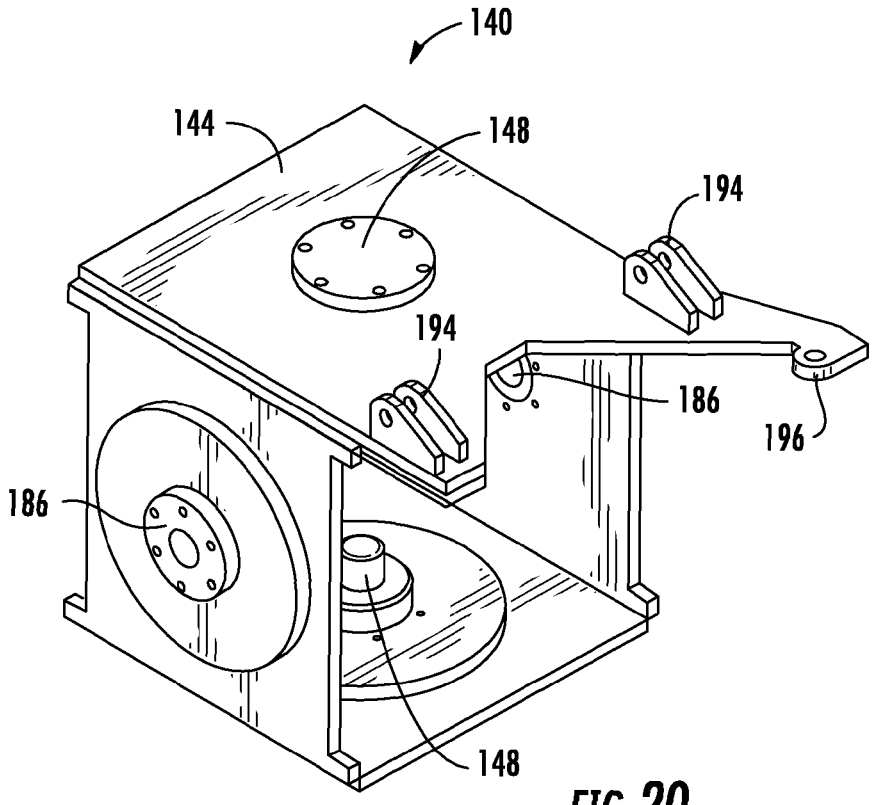

FIG. 20

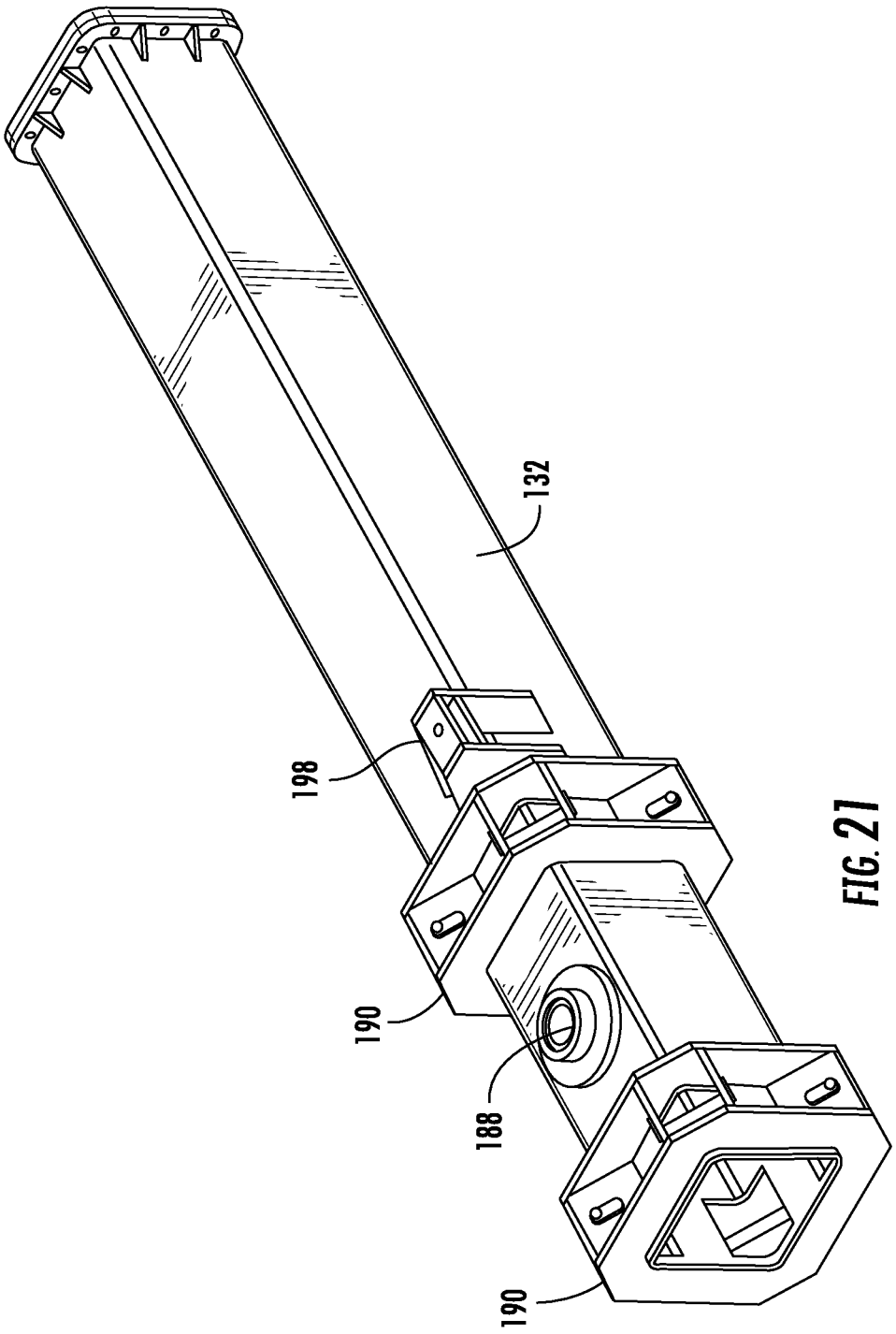

FIG. 21

SLAG CLEARING SYSTEM AND METHOD

BACKGROUND

During the process of making steel in a furnace, slag is created during the melting and refining of the steel within the furnace. The slag may be removed during processing of the steel, and may begin to solidify or become solidified either within the furnace or as the molten slag is removed from the furnace, through a door or other opening in the furnace.

BRIEF SUMMARY

Embodiments of the present invention relate to systems and methods of clearing (e.g., breaking-up, removing, moving, pushing, or the like) solidified slag (e.g., slag that is in the process of solidifying or has at least partially solidified) from the furnace, such as from the slag door or other opening in the furnace. The systems and methods of the present invention comprise moving a ram into and out of position for use and storage, extending and retracting the ram, and moving the ram in the horizontal and vertical directions to clear slag that is in the process of solidifying, or has at least partially solidified, in the slag door, other openings, or within a furnace (e.g., electric arc furnace ("EAF"), blast furnace, any other type of furnace, or the like). The systems and methods of the present invention allow for clearing solidified slag from the furnace without putting workers in a dangerous environment and without the need for expensive retrofitting of the furnace or furnace deck.

One embodiment of the invention is an apparatus comprising a pivot support, a pivot arm operatively coupled to the pivot support, a ram support operatively coupled to the pivot arm, a ram operatively coupled to the ram support, and the ram is configured to remove solidified slag from a slag door opening.

In further accord with an embodiment of the invention, the ram support comprises a vertical ram actuation device. In another embodiment of the invention, the vertical ram actuation device comprises one or more hydraulic actuators operatively coupled to the ram support and the ram, at least one first ram pin operatively coupled to the ram support and the ram, and the hydraulic actuators rotate the ram in the vertical direction around the at least one first ram pin.

In yet another embodiment of the invention, the ram support comprises a horizontal ram actuation device. In still another embodiment of the invention, the horizontal ram actuation device comprises one or more hydraulic actuators operatively coupled to the ram support and the ram, at least one second ram pin operatively coupled to the ram support and the ram, and the hydraulic actuators rotate the ram in the horizontal direction around the at least one second ram pin.

In further accord with an embodiment of the invention, the pivot arm comprises a first pivot arm operatively coupled at a first end to the pivot support and at a second end to the ram support at a first ram support mount; a second pivot arm operatively coupled at a first end to the pivot support and at a second end to the ram support at a second ram support mount; and as the first pivot arm and the second pivot arm rotate, the ram support rotates with respect to the first pivot arm and the second pivot arm at the first ram support mount and the second ram support mount.

In another embodiment of the invention, the ram comprises an extending ram actuation device, and the extending ram actuation device actuates the ram from a retracted position to an extended position.

In yet another embodiment of the invention, the pivot support comprises a base plate support, a tower support operatively coupled to the base plate support, a support shaft operatively coupled to the tower support and the pivot arm, a support actuator operatively coupled to the tower support and the support shaft, and the support actuator rotates the support shaft to move the pivot arm from a pivot arm retracted position to a pivot arm extended position.

In still another embodiment of the invention, the apparatus further comprises an anchor system operatively coupled to the pivot arm or the ram support, and the anchor system is operatively coupled for attachment or detachment to a furnace support.

In further accord with an embodiment of the invention, the pivot support is operatively coupled to a furnace deck, and the furnace deck is located adjacent to a furnace.

In another embodiment of the invention, the ram comprises a pierce tip, and the pierce tip is configured to pierce solidified slag through the slag door opening of a furnace.

Another embodiment of the invention comprises an arm base support, an arm operatively coupled to the arm base support, a ram support operatively coupled to the arm, a ram operatively coupled to the ram support, and the ram is configured to extend and retract to remove solidified slag from a slag door opening.

Another embodiment of the invention is a method comprising positioning a pivot arm into an extended arm position, wherein the pivot arm is operatively coupled to a pivot support; positioning a ram into an extended ram position, wherein the ram is operatively coupled to the pivot arm through a ram support; and clearing solidified slag from a slag door opening.

In another embodiment of the invention, the method further comprises actuating the ram in a vertical direction, wherein the ram is actuated using a vertical ram actuation device. In yet another embodiment of the invention, the vertical ram actuation device comprises one or more hydraulic actuators operatively coupled to the ram support and the ram, at least one first ram pin operatively coupled to the ram support and the ram, and actuating the ram in a vertical direction comprises using the one or more hydraulic actuators to rotate the ram in the vertical direction around the at least one first ram pin.

In still another embodiment of the invention, the method further comprises actuating the ram in the horizontal direction, wherein the ram is actuated using a horizontal ram actuation device.

In further accord with an embodiment of the invention, the horizontal ram actuation device comprises one or more hydraulic actuators operatively coupled to the ram support and the ram, at least one second ram pin operatively coupled to the ram support and the ram, and wherein actuating the ram in the horizontal direction comprises using the one or more hydraulic actuators to rotate the ram in the horizontal direction around the at least one second ram pin.

In another embodiment of the invention, the pivot arm comprises a first pivot arm operatively coupled at a first end to the pivot support and at a second end to the ram support at a first ram support mount; a second pivot arm operatively coupled at a first end to the pivot support and at a second end to the ram support at a second ram support mount; and wherein positioning the pivot arm in the extended position comprises rotating the first pivot arm and the second pivot arm, such that as the first pivot arm and the second pivot arm rotate, the ram support rotates with respect to the first pivot arm and the second pivot arm at the first ram support mount and the second ram support mount.

In yet another embodiment of the invention, the ram comprises an extending ram actuation device, and wherein positioning the ram into an extended position comprises actuating the ram from a retracted position to an extended position using the extending ram actuation device.

In still another embodiment of the invention, the pivot support comprises a base plate support, a tower support operatively coupled to the base plate support, a support shaft operatively coupled to the tower support and the pivot arm, a support actuator operatively coupled to the tower support and the support shaft, and positioning the pivot arm into an extended position comprises rotating the support shaft to move the pivot arm from a pivot arm retracted position to the pivot arm extended position.

In further accord with an embodiment of the invention, the method further comprises operatively coupling the pivot arm to a furnace support using an anchor system, wherein the anchor system is operatively coupled for attachment or detachment to the furnace support.

In another embodiment of the invention, the pivot support is operatively coupled to a furnace deck, and wherein the furnace deck is located adjacent a furnace.

In yet another embodiment of the invention, the ram comprises a pierce tip, and wherein clearing solidified slag from a slag door opening comprises piercing the solidified slag using the pierce tip.

Another embodiment of the invention is a method comprising positioning an arm into an extended arm position, wherein the arm is operatively coupled to an arm base support; positioning a ram into an extended ram position, wherein the ram is operatively coupled to the arm through a ram support; and clearing solidified slag from a slag door opening.

The features, functions, and advantages that have been discussed may be achieved independently in various embodiments of the present invention or may be combined in yet other embodiments, further details of which can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Having thus described embodiments of the invention in general terms, reference will now be made to the accompanying drawings, wherein:

FIG. **1** illustrates a process flow for using a slag clearing system to clear solidified slag, in accordance with one embodiment of the present invention;

FIG. **2** illustrates a perspective view of an electric arc furnace and slag clearing system with an arm in a retracted arm position, in accordance with one embodiment of the present invention;

FIG. **3** illustrates a perspective view of an electric arc furnace and slag clearing system with an arm in an extended arm position, in accordance with one embodiment of the present invention;

FIG. **4** illustrates a perspective view of an electric arc furnace and slag clearing system with an arm in an extended arm position and a ram in an extended ram position, in accordance with one embodiment of the present invention;

FIG. **5** illustrates a perspective view of a slag clearing system with an arm in a retracted arm position, in accordance with one embodiment of the present invention;

FIG. **6** illustrates a perspective view of a slag clearing system with an arm in an intermediate arm position between a retracted arm position and an extended arm position, in accordance with one embodiment of the present invention;

FIG. **7** illustrates a perspective view of a slag clearing system with an arm in an intermediate arm position between a retracted arm position and an extended arm position, in accordance with one embodiment of the present invention;

FIG. **8** illustrates a perspective rear view of a slag clearing system with an arm in an extended arm position, in accordance with one embodiment of the present invention;

FIG. **9** illustrates a perspective front view of a slag clearing system with an arm in an extended arm position, in accordance with one embodiment of the present invention;

FIG. **10** illustrates a perspective view of a slag clearing system with an arm in an extended arm position and with a ram in an extended ram position, in accordance with one embodiment of the present invention;

FIG. **11** illustrates a perspective view of a slag clearing system with an arm in an extended arm position and with a ram in an extended ram position actuated in a first horizontal direction, in accordance with one embodiment of the present invention;

FIG. **12** illustrates a perspective view of a slag clearing system with an arm in an extended arm position and with a ram in an extended ram position actuated in a second horizontal direction, in accordance with one embodiment of the present invention;

FIG. **13** illustrates a perspective view of a slag clearing system with an arm in an extended arm position and with a ram in an extended ram position actuated in a vertical direction, in accordance with one embodiment of the present invention;

FIG. **14** illustrates a front view of a slag clearing system with an arm in an extended arm position and with a ram in an extended ram position actuated in a horizontal direction, in accordance with one embodiment of the present invention;

FIG. **15** illustrates a front view of a slag clearing system with an arm in an extended arm position and with a ram in an extended ram position actuated in vertical and horizontal directions, in accordance with one embodiment of the present invention;

FIG. **16** illustrates a perspective view of a pivot support, in accordance with one embodiment of the present invention;

FIG. **17** illustrates a perspective view of a pivot support arm, in accordance with one embodiment of the present invention;

FIG. **18** illustrates a perspective view of a pivot actuation arm, in accordance with one embodiment of the present invention;

FIG. **19** illustrates a perspective view of an outer ram support housing, in accordance with one embodiment of the present invention;

FIG. **20** illustrates a perspective view of an inner ram support housing, in accordance with one embodiment of the present invention; and

FIG. **21** illustrates a perspective view of a ram housing, in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Embodiments of the present invention will now be described more fully hereinafter with reference to the accompanying drawings, in which some, but not all, embodiments of the invention are shown. Indeed, the invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements. Like numbers refer to like elements throughout.

FIG. **1** illustrates a slag clearing process **1** in accordance with one embodiment of the invention. During the process of making steel, slag is formed and floats on the surface of the melting and molten steel. The slag is a by-product of the steel making process and is formed from the impurities that are separated from melting steel. Slag is present in the process of smelting ore to make steel, and when scrap steel is melted in an electric arc furnace. The slag can be beneficial to the steel making process for creating a blanket that covers the walls and arcs of the furnace, which increases the thermal efficiency, provides better arc stability for increasing electrical efficiency, and prevents damage to the furnace from radiant heat. The foaming slag is in the molten liquid form and is often present throughout the steelmaking process. In some instances, at least a portion of the slag may be removed, such as if too much slag has formed in the furnace, or before the process of tapping the furnace to remove the molten steel begins. In order to remove the slag from the furnace, a slag door on the side of the furnace wall is opened and the furnace is tilted to pour at least some of the molten slag out of the furnace. The slag may be poured into a slag pot located below the furnace deck, which is positioned to catch the slag being poured from the furnace. As the molten slag is poured out of the slag door opening, some of the slag begins to cool. The furnace walls are often water cooled to prevent the molten metal and electric arcs from damaging the furnace walls. Therefore, as molten slag is poured out of the slag door opening, the water-cooled edges of the slag door, and/or the outside air, at least partially solidify some of the molten slag exiting the slag door opening. If too much of the slag solidifies, the slag door opening may become blocked and the amount of slag that can be poured out of the slag door opening may be reduced or even stopped completely. In other situations, such as after the slag has been removed and the furnace prepared for tapping, or otherwise after tapping, the slag may also solidify around the slag door, on top of the remaining molten metal in the furnace, or within the furnace in general. The slag clearing system and process of the present invention may be used in order to break apart, remove, or otherwise clear the solidifying or solidified slag from different areas of the furnace, and in particular, from the slag door opening.

FIG. **1** generally illustrates a process for using a slag clearing system **100** to clear solidified slag from the slag door opening. The slag clearing system **100** comprises an arm base support (e.g., pivot support **110**), an arm (e.g., a pivot arm **120**), a ram **130**, and a ram support **140**. The pivot support **110** is operatively coupled to the decking that surrounds the EAF at a location off to the side of, or adjacent to, the EAF. The pivot arm **120** is rotated from a retracted arm position to an extended arm position, and thereafter, the ram **130** is actuated from a retracted arm position to an extended ram position, to clear solidified slag from the slag door opening. The ram **130** may also be moved in vertical and horizontal directions by either moving the ram support **140**, or moving the ram **130** with respect to the ram support **140**, in order to further clear solidified slag from the slag door opening.

As illustrated in block **10** of FIG. **1**, the slag clearing process **1** comprises positioning the arm of the slag clearing system **100** into an extended position. For example in the illustrated embodiment the arm is a pivot arm **120** and positioning the arm comprises rotating the pivot arm **120** from a retracted pivot arm position (see FIGS. **2** and **5**) into an extended pivot arm position (see FIGS. **3**, **8**, and **9**). In the illustrated embodiment as shown in FIGS. **7** and **8**, and as described in further detail later, the pivot arm **120** may comprise a first pivot support arm **122**, and a second pivot actuation arm **124**. The pivot support arm **122** and the pivot actuation arm **124** are both secured to a ram support **140** at first ends and at different locations on the ram support **140**, such that as the pivot support arm **122** is rotated into the extended arm position the pivot actuation arm rotates the ram support **140** away from the pivot support arm **122** and into the desired position in front of the slag door. In other embodiments of the invention, the pivot arm **120** may comprise a single arm that is operated by hydraulics, gear system, or other devices that both position the arm of the slag clearing system **100** into the extended arm position, and also position the ram support **140** in the desired orientation in front of the slag door. In still other embodiments of the invention, the pivot arm **120** may be a different type of arm that folds up in one or more locations to further compact the slag clearing system **100** when the arm is located in the retracted arm position. In still other embodiments of the invention the pivot arm **120** may also fold up. In still other embodiments of the invention the arm may work in a number of different ways to move between an extended arm position and a retracted arm position.

As illustrated in block **20** of FIG. **1**, one or more anchor systems **160** (see FIGS. **3**, **4**, **5**, and **9**) may be utilized to operatively couple the pivot arm **120** to the furnace **200** or furnace deck **230**. In some embodiments the pivot arm **120** is operatively coupled to a furnace support bar **220** that is operatively coupled to the furnace **200** or the furnace deck **230**. In some embodiments, the anchor system **160** may be operatively coupled to the ram support **140**. The anchor system **160**, as illustrated, may be one or more anchor members **162** with one or more hooks **164**, which may be operatively coupled to the furnace support bar **220** when the pivot arm **120** or other type of arm is located in the extended arm position. The anchor members **162** may be extended or retracted for coupling and decoupling the pivot arm **120** from the furnace **200**, furnace deck **230**, or other support structure adjacent the furnace **200**. The anchor system **160** may be extended or retracted through the use of an actuator, such as a hydraulic actuator. The anchor system **160**, as explained in further detail later, may be utilized to provide an anchor for supporting the slag clearing system **100** as the ram **130** clears the solidified slag from the opening of the slag door **210** of the furnace **200**. The anchor system **160** may be used to provide an opposing force for the ram **130** as the ram **130** is extended to clear solidified slag from the furnace **200**. Without the anchor system **160** the pivot arm **120** may not provide enough of an opposing force for the ram **130**, such that as the ram **130** contacted the solidified slag instead of clearing the slag the ram **130** could move the pivot arm **120** from the extended position back to an intermediate position. In other embodiments of the invention, the anchor system **160** may be operatively coupled to another component of the slag clearing system **100** and may be operatively coupled to other locations on the furnace **200**, to a location on the furnace deck **230**, or otherwise to another component attached to the furnace **200** or furnace deck **230**, in order to provide an anchor during the slag clearing process.

Block **30** of FIG. **1** illustrates that the ram **130** of the slag clearing system **100** is moved from a retracted ram position (see FIGS. **3**, **8**, and **9**) into an extended ram position (see FIGS. **4** and **10-13**), in order to clear out at least some of the solidified slag from the slag door opening. In the illustrated embodiment, as explained in further detail later, the ram **130** may comprises a ram housing **132**, an actuating ram **134**, and a piercing ram **136**, with a pierce head **138** attached to the piercing ram **136**. The ram **130** is actuated between a retracted ram position and an extended ram position. In the illustrated embodiment the actuating ram **134** is extended and retracted using a ram actuating system comprising actuators, such as

hydraulic actuators (not illustrated), located either within or outside of the ram **130** or ram housing **132**. The actuating system may also comprise rollers **192** to facilitate the extension and retraction of the ram **130**. The rollers **192** may be operatively coupled to the ram housing **132**, such as to the ram supports **190** of the ram housing **132**. In other embodiments of the invention, the ram **130** may have more or less components than are described herein, which may or may not be retractable or extendable between operation and storage of the ram **130**. For example, there may be two actuating rams that are both extendable relative to the ram housing **132**, as well as to each other.

As illustrated in block **40** of FIG. **1**, the ram **130** may also be moved in a vertical direction (e.g., vertically up or down) using a vertical ram actuation device **154** (see FIGS. **13** and **15**). In the illustrated embodiment, the ram support **140** may comprise a ram support outer housing **142** and a ram support inner housing **144** operatively coupled to each other through first pivot pins **146** and a vertical actuation device **154**, such as one or more actuators (e.g., hydraulic actuators). The vertical actuation device **154** is operatively coupled to the support outer housing **142** and the support inner housing **144**, such that when the vertical actuation device **154** is actuated the inner housing **144** is rotated around the first pivot pins **146** for moving the ram **130** in the vertical direction. The vertical movement allows the ram **130** to access and clear the solidified slag from different vertical locations within the opening of the slag door **210**. In other embodiments of the invention, the ram **130** may be moved in a vertical direction using other types of vertical ram actuation devices **154** and structural configurations.

Block **50** of FIG. **1**, illustrates that the ram **130** of the slag clearing system **100**, may be moved in a horizontal direction (e.g., horizontally to the left or right) using a horizontal ram actuation device **152** (see FIGS. **11**, **12**, and **14**). In the illustrated embodiment, the ram support **140** may comprise a ram support inner housing **144** operatively coupled to the ram housing **132** through second pivot pins **148** and a horizontal actuation device **152**, such as one or more actuators (e.g., hydraulic actuators). The horizontal actuation device **152** is operatively coupled to the ram support inner housing **144** and the ram **130** (e.g., the ram housing **132**). When the horizontal actuation device **152** is actuated, the ram **130** is rotated around the second pivot pins **148** within the ram support inner housing **144**, such that the ram **130** is moved in the horizontal direction. The horizontal movement allows the ram **130** to access and clear the solidified slag from horizontal locations within the opening of the slag door **210**. In other embodiments of the invention, the ram **130** may be moved in a horizontal direction using other types of horizontal ram actuation devices **154** and structural configurations.

As illustrated in block **60** of FIG. **1**, after the solidified slag in the slag door is sufficiently cleared by the ram **130**, the ram **130** may be moved back into a retracted position for storage using the ram actuating system. In the illustrated embodiment, the actuating ram **134** is pulled back into the ram housing **132**, and the piercing ram **136** remains located outside of the ram housing **132**.

Block **70** of FIG. **1** illustrates that the pivot arm **120** may be moved back into a retracted pivot position for storage until the slag clearing system **100** is required in the future for additional slag clearing. Typically, the opening of the slag door **210** may be cleared every time the furnace **200** is tipped to remove molten slag. In the illustrated embodiment, as previously discussed with respect to moving the pivot arm **120** into the extended arm position, the pivot arm **120** comprises a first pivot support arm **122**, and a second pivot actuation arm **124**. The pivot support arm **122** and pivot actuation arm **124** are both secured to the ram support **140** at different locations, such that as the pivot support arm **122** is rotated back into the retracted arm position, the pivot actuation arm **124** rotates the ram support **140** into a retracted position against the pivot support arm **122**. In other embodiments of the invention, the pivot arm **120** may comprise a single arm that is operated by hydraulics, gear assemblies, and/or other devices to both rotate the slag clearing system **100** into the retracted pivot position and to position the ram support **140** in the desired retracted position. In still other embodiments of the invention, the pivot arm **120** may fold in one or more locations along the arm to further compact the slag clearing system **100** when the pivot arm **120** is located in the retracted arm position.

The slag clearing system **100** has been generally described with respect to the slag clearing process **1** of FIG. **1**. However, the illustrated slag clearing system **100** and alternative embodiments of the invention will be described in further detail below. As illustrated in FIGS. **2** and **3** the slag clearing system **100** may be secured to the furnace deck **230** on one side of the furnace **200** such that access to the furnace, for example to the opening of the slag door **210**, is not obstructed by the slag clearing system **100** when the pivot arm **120** of the slag clearing system **100** is located in the retracted arm position. In the illustrated embodiment, the slag clearing system **100** is located to the right of the furnace **200** and slag door **210**; however, in other embodiments the slag clearing system **100** may be located to the left of furnace **200** and slag door **210**, and consequently, the components of the slag clearing system **100** would be in the opposite configuration as they are illustrated and described herein. Multiple slag clearing devices **100** may be installed in various positions as needed when a facility has two or more furnaces.

FIG. **5** illustrates one embodiment of the slag clearing system **100** comprising a pivot support **110**, a pivot arm **120**, a ram **130**, and a ram support **140**. The pivot support **110** comprises a pivot support base **112** that is used to operatively couple the slag clearing system **100** to the furnace deck **230**, for example through the use of bolts or other coupling means. The pivot support based **112** is operatively coupled (e.g., welded in the illustrated embodiment) to a pivot support tower **114**. In some embodiments the pivot support tower comprises mounting plates **115**, **117**, that are used to secure the pivot arm **120** (e.g., the pivot support arm **122** and the pivot actuation arm **124**). In the illustrated embodiment the pivot arm is operatively coupled to the support tower **114** through the use of a pivot support shaft **116**. The support tower **114** is further operatively coupled to a pivot arm actuator **118**, which is in turn operatively coupled to the pivot support shaft **116**. In the illustrated embodiment the pivot arm actuator **118** is a rack and pinion actuator that may by hydraulically and/or electrically operated. In other embodiments of the invention, the pivot arm actuator **118** may comprise a drive screw, a rod and piston, or other type of actuation device. Furthermore, bearings may be utilized on the pivot support tower **114** to allow the pivot support shaft **116** to rotate within the pivot support tower **114** as the pivot arm **120** is extended and retracted.

As illustrated by FIGS. **5** through **9**, the pivot support **110** and the pivot arm **120** are configured to allow the slag clearing system **100** to rotate from a retracted arm position, to intermediate arm positions, and finally to an extended arm position. Instead of rotating the ram **130** into position in front of the slag door **210**, in some alternative embodiments of the invention the pivot arm **120** may be a different type of arm that may be retracted and extended using a hinged accordion configuration, collapsible configuration (e.g., similar to the

ram disclosed herein), or other type of configuration. The other types of arms may also allow a slag clearing system **100** to be retracted away from the furnace **200** and slag door **210** to allow access to the furnace **200** and slag door **210** when in storage, and extended to a position in front of the furnace **200** and slag door **210** when clearing slag from the opening in the slag door **210** or from within the furnace **200** itself.

FIGS. **7** and **8** illustrate an embodiment of the invention, in which the pivot arm **120** comprises a first pivot support arm **122** and a second pivot actuation arm **124** that work in conjunction with each other to rotate the ram support **140** into position in front of the slag door **210**. In the illustrated embodiment, the support pivot arm **122** is used as a structural support for the ram support **140** and the ram **130**, while the pivot actuation arm **124** is used to pivot the ram support **140** away from the pivot support arm **122**. In some embodiments of the invention the pivot support arm **122** is operatively coupled to the pivot support **110** at the pivot support mounts **115** for rotation, as previously described with respect to the pivot arm **120**. The pivot actuation arm **124** is also operatively coupled to the pivot support **110** at the pivot actuation mounts **117** in a similar fashion for rotation, as described with respect generally to the pivot arm **120**. As illustrated in FIG. **19**, the pivot support arm **122** is operatively coupled to the ram support **140** at a first ram support mount **182**, and the pivot actuation arm **124** is operatively coupled to the ram support **140** at a second ram support mount **184**. Therefore, as illustrated by FIGS. **5** through **9** as the slag cleaning system **100** is positioned into place for clearing slag, the support pivot arm **122** and the pivot actuation arm **124** rotate the ram support **140** about the first ram support mount **182** and the second ram support mount **184**, such that the ram **130** and ram support **140** move from a position that is substantially parallel with the pivot support arm **122** and pivot actuation arm **124** to a position that is substantially perpendicular with the pivot support arm **122** and pivot actuation arm **124**.

FIG. **10** illustrates an embodiment of the invention in which the ram **130** is moved into the extended ram position. In the illustrated embodiment, the ram **130** comprises a ram housing **132**, an actuating ram **134**, and a piercing ram **136**, with a pierce head **138** operatively coupled to the piercing ram **136**. As illustrated in FIGS. **10** and **21**, the ram housing **132** has roller supports **190** that house one or more rollers **192**, which in the illustrated embodiment comprise four rollers **192** in each roller support **190** for contacting the four edges of the actuating ram **134** as it is extended an retracted within the ram housing **132**. In one embodiment, the actuating ram **134** is extended and retracted within the ram housing **132** using a ram actuating system comprising one or more actuators (not illustrated), such as hydraulic actuators. The one or more actuators may be located outside of or inside the ram **130**, such as attached to the outer surface of the ram housing **132** or located within the ram housing **132** itself. In this embodiment the rollers **192** are not powered and act as a guides on the outside of the actuating ram **134** to facilitate the movement of the actuating ram **134** within the ram housing **132**. In other embodiments of the invention, the ram actuating system may drive the rollers **192** through the use of a powered device, such as through the use of motors. In other embodiments of the invention, the actuating ram **134** may be moved with respect to the ram housing **132** through the use of a track system, rail system, or in some embodiments the ram housing **132** itself may be a hydraulic cylinder.

In the illustrated embodiment the ram **130** has a piercing ram **136** section coupled to the actuating ram **134** section, such that the piercing ram **136** is not retracted within the ram housing **132**. In operation the piercing ram **136** has a piercing head **138**, such that both the piercing ram **136** and the piercing head **138** are inserted, at least partially, into the opening of the slag door **210** and through the molten slag and solidified slag exiting the opening of the slag door **210**. Consequently, some slag may solidify at least partially on the piercing ram **136** and/or piercing head **138**. In the illustrated embodiment, the piercing ram **136** may not be retracted into the ram housing **136** in order to prevent slag from accumulating on or within the ram housing **136**, rollers **192**, and other components of the ram **130**. In other embodiments of the invention the piercing ram **136** may be retractable into the ram housing **132** such that the solidified slag on the piercing ram **136** may be removed by the ram housing **132** or another device as the piercing ram **136** is retracted into the ram housing **132**.

In some embodiments of the invention the piercing head **138** has a blade or a point that operates to clear the slag from the slag door by slicing, cutting, breaking apart, or otherwise disrupting the solidified slag using the piercing head **138** of the ram **130**. In other embodiments of the invention, the ram **130** may have more or fewer sections (e.g., multiple actuating rams **134**, a single section that acts as both the actuating ram **134** and piercing ram **136**, or the like) that may or may not be retractable or moveable for operation and storage purposes.

In some embodiments of the invention the ram **130** may be configured with up to fifty-two (52) tons of force (or more or less), to provide ample force for clearing the slag from the opening of the slag door **210**, clearing slag within the furnace **200**, moving material within the furnace **200**, or the like. As previously discussed, in order to counter the force of the ram **130** one or more anchor systems **160** may be used to operatively couple (e.g., removeably couple) the slag clearing system **100** (e.g., pivot arm **120**, ram **130**, ram support **140**, or the like) to the furnace **210**, furnace deck **230**, other structural support attached to the furnace **210** or furnace deck **230** (e.g., support bar **220**), or the like, during clearing of the slag.

FIGS. **11** through **15**, **19**, **20**, and **21** illustrate an embodiment of the present invention in which the ram **130** is configured to move in the horizontal direction and the vertical direction in order to clear solidified slag from the opening of the slag door **210**. In the illustrated embodiment, the ram support **140** may comprise a support outer housing **142** as illustrated in FIG. **19**, and a support inner housing **144** as illustrated in FIG. **20**. The support outer housing **142** and the support inner housing **144** may be operatively coupled to each other by inserting the first pivot pins **146** on the outer housing **142** into the support apertures **186** of the inner housing **144** that are configured to receive the first pivot pints **146**. Consequently, the inner housing **144** may rotate vertically in an up or down direction with respect to the support outer housing **142** around the first pivot pins **146**. Furthermore, the support inner housing **144** may be operatively coupled to the ram **130** through the ram housing **132**. The support inner housing **144** may comprise second pivot pins **148**, which are operatively coupled (e.g., inserted into) to ram housing apertures **188** (e.g., female fittings, counter bore holes, or the like), such that the ram **130** may be actuated in the horizontal direction with respect to the second pivot pins **148**.

FIGS. **11** through **15**, **19**, **20**, and **21** further illustrate that the support outer housing **142** is also operatively coupled to the support inner housing **144** by the vertical actuation device **154**. In the illustrated embodiment the vertical actuation device **154** comprises two actuators, such as hydraulic actuators, that are secured on a first end to the support outer housing **142** and on a second end to the vertical actuator mounts **194** of the inner housing **144**. Furthermore, the support inner housing **144** is operatively coupled to the ram housing **132** through the use of a horizontal actuation device **152**. In the

illustrated embodiment, the horizontal actuation device **152**, is a single actuator, such as a hydraulic actuator, that is operatively coupled on a first end to a horizontal actuator mount **196** on the inner housing **144**, and operatively coupled on a second end to a ram housing actuator mount **198**. The vertical actuation device **154** and the horizontal actuation device **152** allow for actuation of the ram **130** in the horizontal and vertical directions in order to remove the solidified slag or solidifying slag from various locations throughout the opening of the slag door **210** depending on where the slag is solidifying.

In alternative embodiments of the invention, the described and illustrated vertical and horizontal movement of the ram **130** based on the outer support housing **142** and inner support housing **144** may be reversed, such that the inner support housing **144** may be moveable with respect to the outer support housing **142** in the horizontal direction, while the ram housing **132** may be moveable with respect to the inner support housing **144** in the vertical direction. In still other embodiments of the invention the ram **130** may be fixed within the inner housing, and thus, the inner support housing **144** may move with respect to the outer support housing **142** in both the vertical direction and horizontal direction. In still other embodiments of the invention, the ram **130** may be operatively coupled to the outer support housing **142**, and thus may be moveable in the vertical and horizontal directions without the use of an inner support housing.

In some embodiments of the invention the slag clearing system **100**, or the individual components thereof (e.g., pivot arm **110**, ram **130**, or the like) may be controlled by a human operators (e.g., workers) using controls (e.g., joystick, computer, keyboard, or the like). The present invention allows the human operators to operate the slag clearing system **100** from a safe distance away from the potentially dangerous environment around the area of the furnace, and specifically around the opening of the slag door **210** as slag is being removed from the furnace **200**. For example, in some embodiments, the slag clearing system **100** may be operated by human operators from a booth or vestibule located near or adjacent the furnace **200**.

Furthermore, in one embodiment of the invention, the human operator controls the slag clearing system **100** through a direct line of sight of the furnace **200** and slag clearing system **100**. For example, the human operator views the slag exiting the opening in the slag door **210** and determines when removal of the solidified slag is required, and thus, maneuvers the slag clearing system **100** accordingly. In other embodiments of the invention, a camera may be operatively coupled to the slag clearing system **100**, such as to the ram **130**, ram support **140**, and/or pivot arm **120**, such that the human operator does not need to have a direct line of sight to the slag clearing system **100**, the furnace **200**, or slag door **210** of the furnace, in order to clear the solidified slag from the opening of the slag door **210**. Consequently, in some embodiments of the invention the human operator may be in a location away from the furnace **200** and slag clearing system **100**, and for example, may be in a location without visual access or may even be located off-site from the furnace.

In other embodiments of the invention, the slag clearing system **100**, or individual components thereof may be controlled automatically by a computer and computer software that automatically actuates the pivot arm **120** and/or ram **130** to clear solidified slag from the slag door **210**. In this embodiment, the operation of the slag clearing system **100** may be part of an automated process that automatically clears solidified slag from the opening of the slag door **210** during the operation of the furnace.

In still other embodiments of the invention, the pivot arm **120** and/or the ram **130** may have stops that prevent a human operator or automated computer system from moving the pivot arm **120** and/or the ram **130** to a location outside of the desired position. For example, limiting the positioning of the pivot arm **120** to the desired extended arm position or retracted arm position using stops prevents damaging the furnace, such as the furnace walls, or other components within the furnace bay. Furthermore, the stops may also limit the movement of the ram **130** in the vertical and horizontal directions, such that the ram **130** may be limited to moving within a predetermined opening of the slag door **210** in order to prevent the ram **130** from damaging the sides of the slag door **210** or the bricks around the sides of the slag door **210**. The ram **130** may also be restricted from extending into an extended ram position within the furnace that would contact an inner wall within the furnace **200** and damaging the furnace wall or bricks within the furnace. Any damage to the slag door and/or furnace bricks may result in unscheduled shutdowns of the furnace **200** for repairs. The stops may comprise physical limits on the slag clearing system **100**, such as physical stoppers on the ram support **140**, or on the vertical ram actuation device **154** or the horizontal ram actuation device **152** (e.g., hydraulic cylinders). In other embodiments of the invention the stops may comprise physical limits or computer software limits on the hardware (e.g., joystick, or the like) and software used to actuate the slag clearing system **100** (e.g., pivot arm **120** and ram **130**)

In still other embodiments of the invention the ram **130** may be able to extend not only through the opening of the slag door **210**, but also extend all the way into the furnace to the wall opposing the opening in the slag door **210**. In some scenarios it may be beneficial to utilize the slag clearing system **100** for performing tasks associated with breaking up solidified slag in areas within the furnace, or moving or breaking up other material located within the furnace that the ram **130** on the slag clearing system **100** may be able to reach. In still other embodiments of the invention the ram **130** may be outfitted with other devices for repairing or reviewing the furnace or components thereof. For example, a camera, probe, sample gathering device, or the like may be attached to the ram **130**.

The embodiments of the invention described and illustrated herein, have been described with respect to the use of an arm that has a pivoting configuration, however, as previously discussed, the arm of the slag clearing system **100** may have different configurations, such as a multiple hinged arm that folds upon itself, an arm that is collapsible upon itself along a longitudinal axis running through the middle of the arm, or another configuration. It should be understood that attaching the ram **130** to the other types of retractable arms is contemplated by this invention. Furthermore, it should be understood that different types of rams may be utilized with the pivot arm **120** disclosed herein to accomplish the results of clearing slag from the opening of the slag door **210**. Moreover, specific types of vertical and horizontal ram actuating devices are described herein, and it should be understood that alternate embodiments of the ram, ram support, vertical and horizontal ram actuation devices, and ram actuating devices, as well as the configurations for operatively coupling these components are contemplated by this application.

While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of, and not restrictive on, the broad invention, and that this invention not be limited to the specific constructions and arrangements shown and described, since various other

changes, combinations, omissions, modifications and substitutions, in addition to those set forth in the above paragraphs, are possible. Those skilled in the art will appreciate that various adaptations, modifications, and combinations of the just described embodiments can be configured without departing from the scope and spirit of the invention. Therefore, it is to be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described herein.

What is claimed is:

1. An apparatus comprising:

a pivot support comprising a pivot support tower, a pivot support shaft operatively coupled to the pivot support tower, and a support actuator operatively coupled to the pivot support shaft;

a pivot arm operatively coupled to the pivot support shaft of the pivot support;

a ram support operatively coupled to the pivot arm;

a ram operatively coupled to the ram support;

wherein the support actuator rotates the support shaft to move the pivot arm from a pivot arm retracted position to a pivot arm extended position; and

wherein the ram is configured to remove solidified slag from a slag door opening.

2. The apparatus of claim **1**, wherein the ram support comprises:

a vertical ram actuation device.

3. The apparatus of claim **2**, wherein the vertical ram actuation device comprises:

one or more hydraulic actuators operatively coupled to the ram support and the ram;

at least one first ram pin operatively coupled to the ram support and the ram; and

wherein the hydraulic actuators rotate the ram in the vertical direction around the at least one first ram pin.

4. The apparatus of claim **1**, wherein the ram support comprises:

a horizontal ram actuation device.

5. The apparatus of claim **4**, wherein the horizontal ram actuation device comprises:

one or more hydraulic actuators operatively coupled to the ram support and the ram;

at least one second ram pin operatively coupled to the ram support and the ram; and

wherein the hydraulic actuators rotate the ram in the horizontal direction around the at least one second ram pin.

6. The apparatus of claim **1**, wherein the pivot arm comprises:

a first pivot arm operatively coupled at a first end to the pivot support and at a second end to the ram support at a first ram support mount;

a second pivot arm operatively coupled at a first end to the pivot support and at a second end to the ram support at a second ram support mount; and

wherein as the first pivot arm and the second pivot arm rotate, the ram support rotates with respect to the first pivot arm and the second pivot arm at the first ram support mount and the second ram support mount.

7. The apparatus of claim **1**, wherein the ram comprises:

an extending ram actuation device; and

wherein the extending ram actuation device actuates the ram from a retracted position to an extended position.

8. The apparatus of claim **1**, wherein the pivot support further comprises:

a pivot support base operatively coupled to the pivot support tower.

9. The apparatus of claim **1**, further comprising:

an anchor system operatively coupled to the pivot arm or the ram support; and

wherein the anchor system is operatively coupled for attachment or detachment to a furnace support.

10. The apparatus of claim **1**, wherein the pivot support is operatively coupled to a furnace deck, and wherein the furnace deck is located adjacent to a furnace.

11. The apparatus of claim **1**, wherein the ram comprises a pierce tip, and wherein the pierce tip is configured to pierce solidified slag through the slag door opening of a furnace.

12. An apparatus comprising:

an arm base support;

an arm operatively coupled to the arm base support;

a ram support operatively coupled to the arm, wherein the ram support comprises a vertical ram actuation device and a horizontal ram actuation device;

a ram operatively coupled to the ram support; and

wherein the ram is configured to extend and retract to remove solidified slag from a slag door opening and actuate in a vertical direction using the vertical ram actuation device and in a horizontal direction using the horizontal ram actuation device to removed solidified slag from areas within the slag door opening.

13. A method comprising:

positioning a pivot arm into an extended arm position from a retracted arm position, wherein the pivot arm is operatively coupled to a pivot support shaft of a pivot support, wherein the pivot support comprises a pivot support tower, the pivot support shaft operatively coupled to the pivot support tower, and a support actuator operatively coupled to the pivot support shaft, and wherein the support actuator rotates the support shaft to move the pivot arm from the retracted position to the extended position;

positioning a ram into an extended ram position, wherein the ram is operatively coupled to the pivot arm through a ram support; and

clearing solidified slag from a slag door opening.

14. The method of claim **13**, further comprising:

actuating the ram in a vertical direction, wherein the ram is actuated using a vertical ram actuation device.

15. The method of claim **14**, wherein the vertical ram actuation device comprises:

one or more hydraulic actuators operatively coupled to the ram support and the ram;

at least one first ram pin operatively coupled to the ram support and the ram; and

wherein actuating the ram in a vertical direction comprises using the one or more hydraulic actuators to rotate the ram in the vertical direction around the at least one first ram pin.

16. The method of claim **13**, further comprising:

actuating the ram in the horizontal direction, wherein the ram is actuated using a horizontal ram actuation device.

17. The method of claim **16**, wherein the horizontal ram actuation device comprises:

one or more hydraulic actuators operatively coupled to the ram support and the ram;

at least one second ram pin operatively coupled to the ram support and the ram; and

wherein actuating the ram in the horizontal direction comprises using the one or more hydraulic actuators to rotate the ram in the horizontal direction around the at least one second ram pin.

18. The method of claim 13, wherein the pivot arm comprises:

a first pivot arm operatively coupled at a first end to the pivot support and at a second end to the ram support at a first ram support mount;

a second pivot arm operatively coupled at a first end to the pivot support and at a second end to the ram support at a second ram support mount; and

wherein positioning the pivot arm in the extended position comprises rotating the first pivot arm and the second pivot arm, such that as the first pivot arm and the second pivot arm rotate, the ram support rotates with respect to the first pivot arm and the second pivot arm at the first ram support mount and the second ram support mount.

19. The method of claim 13, wherein the ram comprises:

an extending ram actuation device; and

wherein positioning the ram into an extended position comprises actuating the ram from a retracted position to an extended position using the extending ram actuation device.

20. The method of claim 13, wherein the pivot support further comprises:

a pivot support base operatively coupled to the pivot support tower.

21. The method of claim 13, further comprising:

operatively coupling the pivot arm to a furnace support using an anchor system, wherein the anchor system is operatively coupled for attachment or detachment to the furnace support.

22. The method of claim 13, wherein the pivot support is operatively coupled to a furnace deck, and wherein the furnace deck is located adjacent a furnace.

23. The method of claim 13, wherein the ram comprises a pierce tip, and wherein clearing solidified slag from a slag door opening comprises piercing the solidified slag using the pierce tip.

24. An method comprising:

positioning an arm into an extended arm position from a retracted arm position, wherein the arm is operatively coupled to an arm base support;

positioning a ram into an extended ram position within a slag door opening, wherein the ram is operatively coupled to the arm through a ram support comprising a vertical ram actuation device and a horizontal ram actuation device; and

clearing solidified slag from the slag door opening by actuating the ram in a vertical direction using the vertical ram actuation device and in a horizontal direction using the horizontal ram actuation device.

25. An apparatus comprising:

an arm base support;

an arm operatively coupled to the arm base support;

a ram support operatively coupled to the arm;

a ram operatively coupled to the ram support; and

an anchor system operatively coupled to the arm or the ram support;

wherein the anchor system is operatively coupled for attachment or detachment to a furnace support; and

wherein the ram is configured to remove solidified slag from a slag door opening.

26. A method comprising:

positioning an arm into an extended arm position from a retracted arm position, wherein the arm is operatively coupled to an arm base support;

operatively coupling the arm or a ram support to a furnace support using an anchor system, wherein the anchor system is operatively coupled for attachment or detachment to the furnace support;

positioning a ram into an extended ram position within a slag door opening, wherein the ram is operatively coupled to the arm through the ram support; and

clearing solidified slag from the slag door opening.

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